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J C Branner

THE AMERICAN GEOLOGIST

A MONTHLY JOURNAL OF GEOLOGY

AND

ALLIED SCIENCES

VOLUME XXI

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CONTENTS.

JANUARY NUMBER.

FEBRUARY NUMBER.

MARCH NUMBER.

APRIL NUMBER.

MAY NUMBER.

JUNE NUMBER.

Errata for Vol. XX.

Page 164, line 14, for "pot" read pool.
Page 165, line 13, for "rhyolite" read hyalite.
Page 334, line 9 from the bottom, for "*tombière*" read *tourbière*.
Page 410, line 8, erase the comma after vote.
Page 417, last line but one, for "deserve" read receive.
Page 418, line 5 from the bottom, for "Stepniow" read Spondiarow.
Page 420, line 2 of small type, for " west side" read east side.

Errata for Vol. XXI.

Page 70, line 1, for "Fraser" read Frazer.
Page 133, line 1, for "Tyrell" read Tyrrell.
Page 133, line 25, for "1898" read 1897.
Page 250, line 19 from the bottom, for "Nuclei" read Nucleus.
Page 250, line 2 from the bottom, for "5th" read 4th.
Page 328, line 10, in place of this line read ogists.] (Am. Geol. vol. 21, pp. 213-219, Apr. 1898.)

Yours Truly
Joseph F. James

THE AMERICAN GEOLOGIST.
VOL. XXI, PLATE I.

THE

AMERICAN GEOLOGIST.

VOL. XXI. JANUARY, 1898. No. 1

JOSEPH FRANCIS JAMES.
1857-1897.

By G. K. GILBERT, Washington.

(Plate I.)

Joseph Francis James was born in Cincinnati, Ohio, February 8, 1857. He died in Hingham, Massachusetts, March 29, 1897. His father, Uriah Pierson James, a bookseller and publisher of Cincinnati, devoted his leisure to scientific work, chiefly the collection and study of the fossils of the Cincinnati group. As a boy Joseph was his father's companion on collecting rambles and his scientific bent was thus early acquired. Under his father's guidance he added the collecting of living plants to the collecting of fossils, and his first publications were in the field of botany. Notes on rare or abnormal plants appeared in the Botanical Gazette in 1877 and 1879, but he had already, at the age of sixteen, made a catalogue of the local flora, which was afterward publisht by the Cincinnati Society of Natural History.

In 1879 he removed to Los Angeles, California, where he engaged in business and intended to make his permanent home, but his plans were deranged by a disastrous fire and finally abandoned. He then joined a railway construction force and traveled through southern California, New Mexico and Arizona, returning to San Francisco. This slow journey in a land strongly contrasted, as to scenery and climate, with the Ohio valley was an important factor in his education, and was peculiarly effective in broadening his view of the relation

of life to environment. Numerous letters to newspapers were written from the field, and his botanical notes were afterward extensively used in more formal writings.

Returning to Cincinnati after two years of western life, he was appointed (1881) custodian of the Society of Natural History, a position he held for six years, and he became also professor of medical botany in the Cincinnati College of Pharmacy. In the first part of this period his interest and work continued in the field of botany, but paleontological and geological papers began to appear in 1884, the Cincinnati group affording the principal themes.

In 1884 he was married to Sarah C. Stubbs, of Cincinnati, who had been a teacher of botany and physiology in the city high school. The union was a happy one, and his later labors had the advantage of a sympathetic and efficient helpmeet. With two sons she survives him.

In 1886 he was elected to the chair of botany and geology of the Miami University, at Oxford, Ohio, but this position was lost two years later through a disruption of the faculty arising from religious prejudices. He was then for one year professor of natural history in the Agricultural College of Maryland. The work of teaching did not prevent the continuance of scientific study, and a number of papers from his pen appeared during this time. In these writings geology, paleontology and botany are about equally represented, the chief subjects being those which had occupied his attention at Cincinnati.

While in Maryland he began work in connection with the United States Geological Survey and in 1889 was appointed on the staff as assistant paleontologist, being assigned to the division of paleozoic paleontology. The acquiring of this position, which for years had been a cherisht ambition, proved only the occasion of another disappointment, for the work it gave him was largely of subsidiary and routine character, not affording the opportunities for authorship to which he had lookt forward. Two years later he received an appointment in the United States Department of Agriculture, having past highest in a special examination by the Civil Service Commission for an assistant vegetable pathologist, and in this capacity he served for four years. Here also his duties were

chiefly routine, and there was little gratification for his ambition in the direction of original research.

Having for many years struggled to support himself by avocations in harmony with his scientific pursuits, and having, either from the accident of environment or from lack of personal adaptation, suffered repeated rebuffs and discouragements, he at last determined to adopt a more remunerative profession and relegate science wholly to leisure hours. Still retaining his official position and work, he devoted his evenings to the study of medicine, and in 1895 graduated from the medical school of Columbian University. The following winter was given to hospital work and bacteriologic study in New York and London, and he then began practice in Hingham, where the last year of his life was spent. A letter from the leader of an exploring expedition to Greenland, inviting him to be the physician of the party, reacht his house the day after his death.

Professor James's scientific work included the acquisition of knowledge through research and its diffusion through popular as well as technical publication. In research he was conscientious and patient, dealing largely with details of classification, generalization and explanation, and though enthusiastic, was not tempted into the field of speculation. No brilliant discoveries nor theories were announced by him, but his contributions to knowledge are substantial and useful. In publication he was not limited either to the record of his own investigations or to the pages of scientific journals, but being deeply imprest with the importance of diffusing scientific knowledge, he appeared often as an expounder of the work of others, and made free use of newspapers and popular journals. The subjoined lists would have been greatly extended by including reviews and book notices, and still more by adding the numerous short articles addrest in one way or another to the general public.

When religious beliefs were under fire at Oxford, professor James was accused of being an agnostic and defended as being essentially a Unitarian. So far as I knew it, his religion was an unswerving devotion to science. Science gave him only a modicum of that fame which is so dear even to the least selfish of her votaries, and she utterly failed to shield him from adversity, but his fealty endured to the end.

LIST OF PAPERS.*

Geological.

1885.

Evidences of beaches in the Cincinnati Group: Science, Vol. V, March, 1885, pp. 231-233.

1886.

Geology of Cincinnati [Part I, Geology]: Jour. Cincinnati Soc. Nat. Hist., Vol. IX, July, 1886, pp. 20-31 [84-95].

Geology and topography of Cincinnati [Part II, Topography]: Jour. Cincinnati Soc. Nat. Hist., Vol. IX, October, 1886, pp. 136-141.

1887.

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Chalcedonized fossils: Science, Vol. X, September, 1887, p. 156.

1888.

Geological section of southwestern Ohio (Abstract): Proc. Am. Assoc. Adv. Sci., 36th meeting (August, 1887), March, 1888, p. 211.

An ancient channel of the Ohio River at Cincinnati: Jour. Cincinnati Soc. Nat. Hist., Vol. XI, July-October, 1888, pp. 96-101.

The Ivorydale well in Mill Creek Valley [Ohio]: Jour. Cincinnati Soc. Nat. Hist., Vol. XI, July-October, 1888, pp. 102-104.

1889.

Remarks upon sedimentation in the Cincinnati Group: Jour. Cincinnati Soc. Nat. Hist., Vol. XII, April, 1889, pp. 34-36.

Curiosities of natural gas: Pop. Sci. Monthly, Vol. XXXIV, April, 1889, pp. 821-826.

An ancient channel of the Ohio at Cincinnati (Abstract): Proc. Am. Assoc. Adv. Science., 37th meeting (August, 1888), May, 1889, p. 196.

The geology of the Montmorenci. A correction in a date: Am. Geologist, Vol. IV, December, 1889, p. 387.

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*Professor James himself compiled a list of his papers "for the use of his boys." That list forms the basis of the bibliography here given, being abridged by the omission of newspaper articles, reviews and short notes, and extended by the addition of a few articles publisht in the last years of his life and one unpublisht paper. The work of verification and extension has been chiefly performed by Miss A. B. Dawson, and the botanical part has been revised also by Mr. E. S. Steele.

1890.

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1891.

A brief history of the Ohio River: Pop. Sci. Monthly, Vol. XXXVIII, April, 1891, pp. 739-748.

On the age of the Pt. Pleasant, Ohio, beds: Jour. Cincinnati Soc. Nat. Hist., Vol. XIV, July, 1891, pp. 93-104. Two plates.

1893.

The Cincinnati ice dam: Am. Geologist, Vol. XI, March, 1893, pp. 199-202.

1894.

On the value of supposed Algæ as geological guides: Am. Geologist, Vol. XIII, February, 1894, pp. 95-101.

The St. Peter's sandstone: Jour. Cincinnati Soc. Nat. Hist., Vol. XVII, July, 1894, pp. 115-135.

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1881.

Catalogue of the fossils of the Cincinnati Group. Cincinnati, 1881. 27 pages.

1881.

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1884-1885.

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1885.

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1886.

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1887.

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Sections of fossils: Science, Vol. X, October, 1887, p. 180.

1887-1888.

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1887.

Microscopic sections of Corals: Science, Vol. X, November, 1887, p. 252.

1888.

Sections of Fossils: Science, Vol. XI, January, 1888, p. 50.

On the Monticuliporoid corals of the Cincinnati Group, with a critical revision of the species (Abstract): Proc. Am. Assoc. Adv. Sci., 36th meeting (August, 1887), March, 1888, p. 223.

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1891.

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1892-1893.

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1892.

The preservation of plants as fossils: Jour. Cincinnati Soc. Nat. Hist., Vol. XV, July, 1892, pp. 75-78.

1893.

Remarks on the genus Arthrophycus, Hall: Jour. Cincinnati Soc. Nat. Hist., Vol. XVI, July-October, 1893, pp. 82-86.

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1895.

[Daimonelix and allied fossil.] (Abstract of paper read before Biological Society of Washington): Science, new series, Vol. I, April, 1895, p. 420.

Remarks on Daimonelix, or "Devil's Corkscrew," and allied fossils: Am. Geologist, Vol. XV, June, 1895, pp. 337-342; plates.

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The first fauna of the earth: Am. Naturalist, Vol. XXIX, October, 1895, pp. 879-887; November, 1895, pp. 979-985.

The Paleontological writings of Uriah Pierson James, compiled, annotated and illustrated by Joseph F. James. In manuscript, ready for publication.

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1879.

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1880.

On the modes of distribution of plants: Pop. Sci. Monthly, Vol. XVII, July, 1880, pp. 365-376.

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1881.

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The century plant: Jour. Cincinnati Soc. Nat. Hist., Vol. IV, October; 1881, pp. 234-236.

Botanical notes from Tuscon: Am. Naturalist, Vol. XV, December, 1881, pp. 978-987.

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1882.

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1883.

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1884.

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1885.

How the pitcher plant got its leaves: Am. Naturalist, Vol. XIX, June, 1885, pp. 567-578; with 11 figures.

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Progress of vegetation in the Ohio Valley: Jour. Cincinnati Soc. Nat. Hist., Vol. VIII, July, 1885, pp. 115-119.

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1886.

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1887.

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1888.

Diseased plums: Botanical Gazette, Vol. XIII, July, 1888, p. 193.

New variety of Asclepias tuberosa [var. flexuosa]: Botanical Gazette, Vol. XIII, October, 1888, p. 271.

Notes on the development of Corynites Curtissii: Bull. Torrey Bot. Club, Vol. XV, December, 1888, pp. 314-315; plate.

1889.

Distribution of Vernonia in the United States: Jour. Cincinnati Soc. Nat. Hist., Vol. XI, January, 1889, pp. 136-140.

Remarks upon Color as a distinguishing feature of certain species of plants: Bull. Torrey Bot. Club, Vol. XVI, October, 1889, pp. 268-270.

1890.

Leaves of Liriodendron (A notice): Vick's Monthly Magazine, Vol. XIII, December, 1890, pp. 385-386.

1891.

Pollen: Its development and use: Pop. Sci. Monthly, Vol. XXXIX, July, 1891, pp. 337-343; with 12 figures.

1892.

Electricity in horticulture: Sci. Am. Supplement, Vol. XXXIII, No. 841, February 18, 1892, pp. 13435-13436.

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Wheat rust and smut: Science, Vol. XX, August, 1892, pp. 93-94.

1893.

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The largest trees in the world: Science, Vol. XXI, March, 1893, p. 123; also Sci. Am. Suplement, April 8, 1893.

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1894.

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1895.

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1881.

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1882.

The Colorado desert: Pop. Sci. Monthly, Vol. XX, January, 1882, pp. 384-390.

Charles Robert Darwin: Jour. Cincinnati Soc. Nat. Hist., Vol. V, July, 1882, pp. 71-77.

1883.

A prehistoric cemetery: Pop. Sci. Monthly, Vol. XXII, February, 1883, pp. 445-458.

1885.

Catalogue of the specimens in the Collection of the Cincinnati Society of Natural History: Jour. Cincinnati Soc. Nat. Hist., Vol. VIII, April, 1885, pp. 31-48.

On the tracks of insects resembling the impressions of plants. [Translated from the French of M. R. Zeiller]: Jour. Cincinnati Soc. Nat. Hist., Vol. VIII, April, 1885, pp. 49-52.

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1886-1887.

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1887.

The Chinese Wall: Science, Vol. X, December, 1887, p. 323.

1888.

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Remarks on the Journal of the Cincinnati Society of Natural History: Jour. Cincinnati Soc. Nat. Hist., Vol. XI, April, 1888, pp. 3-6.

1889-1891.

Notes upon papers read before the Biological Society of Washington, D. C.: Am. Naturalist, Vol. XXIII, January, 1889, pp. 51, 52, 59, 61, 65; Vol. XXIV, November, 1890, pp. 1103-1105; December, 1890, pp. 1220-1224; Vol. XXV, January, 1891, pp. 88-90; March, 1891, pp. 298-299; April, 1891, pp. 400-403.

1889.

The great deserts of the earth: Sci. Am. Supplement, No. 703, June, 1889, pp. 11224-11226.

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1891.

Prehistoric man and the horse in North America: Sci. American, Vol. LXV, September, 1891, p. 161.

1893.

The Scientific Alliance of New York: Science, Vol. XXII, August, 1893, p. 66.

The American Association for the Advancement of Science: Science, Vol. XXII, August, 1893, pp. 104-105.

1895.

Blood examination in disease: Science, New Series, Vol. II, September, 1895, pp. 412-413.

THE DETERMINATION OF THE FELDSPARS.

By N. H. WINCHELL, Minneapolis.

C'est par des efforts de ce genre que nos méthodes micrographiques finiront par conquérir la place qui leur est due dans les programmes universitaires et dans l'enseignement des grandes écoles.—*Fouqué.*

C'est un devoir pour tout pétrographe qui se livre à une étude nouvelle de s'ingénier pour amender et perfectionner les procédés de recherche que lui donne la science contemporaine.—*Fouqué.*

La détermination précise, rapide et relativement facile de tous les éléments feldspathiques des roches est une des conditions indispensable à l'établissement d'une classification rationelle.—*Michel-Lévy.*

On peut en quelque sorte jauger la valeur d'une étude petrographique au soin apporté par l'auteur à déterminer les feldspaths de ses plaques minces.—*Michel-Lévy.*

INTRODUCTION.

Owing to the prevalence of the feldspars in nearly all crystalline rocks their accurate determination is one of the essentials in practical petrography. As they appertain to the monoclinic and the triclinic systems, their investigation involves most of the problems which arise in the use of the petrographical microscope. Hence, as has been remarked by Michel-Lévy* the progress of accurate methods of their determination has been the touchstone of progress in microscopical petrography. This progress is due to the skill of several petrographers—Descloiseaux, Fouqué, Michel-Lévy, Schuster, Federov and others.

The following sketch consists of a presentation chiefly of the methods which have been devised within recent years in

---

*Détermination des feldspaths dans les plaques minces, 1894, p. 2.

France, due to the genius of MM. Fouqué and Michel-Lévy, whose remarkable contributions have attracted the attention of every petrographer.[*] They not only embody, in the latest advanced form, the results of all earlier petrographers, but they extend the means of determination to greater scope and greater refinement.[†] If it shall serve to call the attention of American petrographers, now under the dominance of the German school, to the excellence of the French methods, the object of this sketch will be accomplished.

Preparatory to this it is necessary to recall briefly the principal characters of the feldspars.

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[*] Following are the titles of the original publications to which reference is made above:

Michel-Lévy:—

De l'emploi du microscope polarisant à lumïère parallel pour l'étude des plaques minces des roches éruptives. Ann. d. Mines, Dec. 1877.

Mésure du pouvoir biréfringent et positions d'égale intensité lumineuse des minéraux en plaque mince, 1884. Bul. Soc. Min. France.

Minéraux des roches (with A. Lacroix), 1888, Baudry & Cie., Paris.

Sur les moyens: (1) de réconnaitre les sections paralleles à g' (010) des feldspaths dans les plaques minces; (2) d'en utiliser les propriétés optiques. Comptes Rendus des Séances de l'Académie des Sciences, t. CXI., p. 700, 1890.

Etudes sur les roches des Puys et du Mont-Dore. Bul. Soc. Géol. France, Réunion extraordinaire à Clermont-Ferrand, 1890, p. 674 et suiv. Plusieurs Contributions.

Etudes sur la détermination des feldspaths dans les plaques minces au point de vue de la classification des roches. Baudry & Cie., Paris, 1894, p. 171. 8 planches.

Ditto:—

Deuxième fascicule. Sur l'éclairement commun des plagioclases zonés: Propriétés optiques de microcline. Baudry & Cie., Paris, 1896.

Fouqué:—

Minéralogie micrographique. Roches éruptives françaises (avec Michel-Lévy). Mem. de la carte géol. de France. Ministère des Travaux publiques. Paris, 1879.

Contribution à l'étude des feldspaths des roches volcaniques. Bul. Soc. Min. Fran., 1894.

Lacroix:—

Lastly, these principles and methods have been extensively applied by Prof. A. Lacroix in his late works: Les enclaves des roches volcaniques (Ann. Acad. Macon, vol. X, 1893), and Minéralogie de la France et de ses colonies (Paris: Baudry & Co., 1893-6); where will also be found a large number of new optic properties of the various minerals, many of them pertaining to the feldspars.

[†] The writer is under great obligation to Messrs. Michel-Lévy, Fouqué and Lacroix for assistance and critical suggestions in the preparation of this sketch, and to Dr. U. S. Grant in its revision.

GENERAL CHARACTERS OF THE FELDSPARS.

The feldspars are all closely related as to form, and their chemical composition varies from one to the other according to the prevalence of the alkaline bases. They are silicates of alumina with an alkaline base, and hence are colorless.

Forms of the Feldspars.

Orthoclase, microcline and anorthoclase may be associated in one group on account of their near identity of form and the similarity of their bases. Orthoclase is monoclinic*, and anorthoclase scarcely varies from monoclinic. Figures 1, 2 and 3 represent common, simple forms of orthoclase. The angle 001 ∧ 010 is 90°. In anorthoclase it is practically 90°. In the upper positive quadrant of the crystal it is a little more and on the negative quadrant a little less than 90°. In the lower right quadrant it is less and in the lower left quadrant it is more than 90°. In microcline and anorthoclase, therefore, as with the plagioclases, the basal plane of the crystal in its conventional position, i. e., with the vertical axis (*c*) perpendicular, tips not only forward toward the observer, but slightly toward the right. The angle 001 ∧ 100 is 116°7′ in orthoclase and microcline, and 116°22′ in anorthoclase.

Orthoclase is frequently elongated in the plane of symmetry, that is, parallel to the face 010, in the direction of the horizontal axis (a), the crystals then taking the forms of quadratic prisms, the real prism faces 110 and 110 being reduced to comparatively insignificant dimensions (fig. 3). Anorthoclase is often elongated parallel to the edge $110{:}1\bar{1}0$.

The plagioclases are distinctly triclinic, yet the angle α does not depart far from 90°. Their forms therefore are quite near that of orthoclase. The obtuse angle α (001 ∧ 010) in the plagioclases is as follows: albite, 93°36′; oligoclase, 93°50′; andesine, 93°(?); labradorite, 93°20′; anorthite, 94°10′.

By the development of the faces 001 and 010 they are subjected to the same elongation as orthoclase (fig. 3), and in addition they are sometimes elongated parallel to the edge 001:100. This elongation produces the variety pericline of albite (fig. 15), and when twinned gives rise to pericline striations which appear in all the plagioclases on 100 and 010.

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*According to Mallard orthoclase is triclinic.

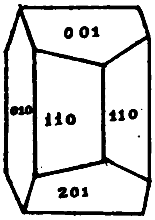

FIG. 1.

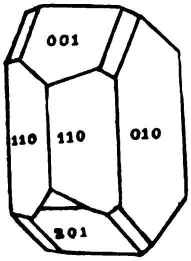

FIG. 2.
Simple Forms of Orthoclase.

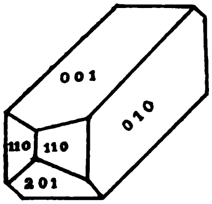

FIG. 3.

Cleavages.

The feldspars all possess an easy cleavage parallel to the base (001) and another less evident parallel to the pinacoid 010. There are also rudimentary, often irregular, and coarser cleavages parallel to the prism faces 110 and $\bar{1}10$, etc. The basal cleavage is always visible if the thin section be not too thick, nor parallel to the base. That parallel to 010 is parallel to the albite striations, and disappears in sections cut parallel to 010. In orthoclase these cleavages form a right angle with each other. In all the other feldspars they are oblique. These cleavages are best observed in sections rather thin, and on lowering the condenser.

Twinning.

The feldspars are all subject to twinning*. Orthoclase is especially frequent in the form of Carlsbad twins, but also shows the forms of Manebach (Four-la-Brouque) and Baveno (figs. 4, 5 and 6).

The Manebach type (fig. 4) has the basal plane as composition face, and the axis about which the crystal turns is a line perpendicular to the base 001 (Lacroix). The cleavages 001, of one twin, are parallel to those of 001 of the other. The same is true of the cleavages 010. But their extinctions have opposite signs, only one of the twins being in the conventional position (p. 14).

In the Carlsbad form the twins are united by some plane, usually 010, parallel to the vertical axis (fig. 5). One is turned 180° from the position of the other about the common vertical axis. In a thin section of a Carlsbad twin the pinacoidal

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*The French word "macle" might appropriately and conveniently be substituted for the word twinning.

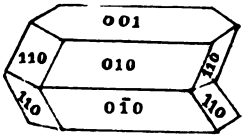

FIG. 4. Manebach.

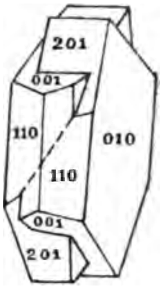

FIG. 5. -Carlsbad.

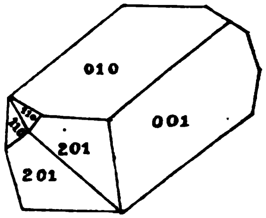

FIG. 6.—Baveno.

cleavage (010) in one twin is parallel with that in the other, and unless the section be cut in a zone whose axis is either parallel or perpendicular to the face 010, the different cleavages all form oblique angles with one another. If a section be in a zone whose axis is either parallel or perpendicular to the face 010, the cleavages will stand at right angles.

In the Baveno twin the plane of association is the clinodome 021. Sections cutting such a twinned crystal present square or rhombic outlines, the cleavages being parallel to the sides. The line separating the twins runs diagonally, from corner to corner, as seen in figures 7 and 8. These sections are not uncommon, since in the case of the Baveno-twinned crystals they are also usually elongated parallel to the edge 001:010.

Baveno twins in thin section.

FIG. 7. -Perpendicular section. FIG. 8.—Oblique section.

The basal faces and the brachypinacoids which form the surfaces of the prism are at right angles to each other.

While these forms prevail in the monoclinic feldspars it is not uncommon that they unite, in the triclinic feldspars, with the albite and pericline types of twinning, which are rarely absent in the latter.

Albite and Pericline Twinning.—All the plagioclastic feldspars are characterized by fine polysynthetic twinning, which

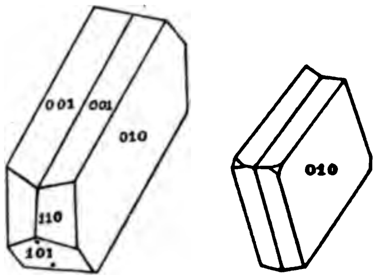

FIG. 7a. FIG. 8a.

Albite-Twinned Feldspathic Microlites.

produces a fine superficial striation visible to the naked eye; it is caused by a succession of changes in direction of growth of the crystal, each layer being turned from its fellow preceding by an angle of about 172°. When the twinning axis is a normal to 010, this twinning forms the albite type. When it is parallel to *b* it forms the pericline type. In the albite type the lamellæ are parallel to 010 and produce striations on the sides 001 and 100. They are not visible in thin sections parallel to 010, but in all others they are apparent in narrow bands which polarize and extinguish alternately, on being rotated between crossed nicols, the colored bands being parallel to the pinacoidal cleavage. The external pericline striations are visible on all faces of the crystal. If striations appear on the face 010, they are necessarily of the pericline type. In thin sections, if the pericline twinning exists, it is visible in sections cut in all directions except parallel to the composition face, and in andesine this face is practically parallel to the base 001. In the other plagioclases it is in the same zone, but makes an angle with the base (fig. 16.)

Figures 7a and 8a represent each a pair of microlitic twins of the albite type, the former having an elongation parallel to the axis *a* and the latter a flattening parallel to 010.

Figure 9 represents a triclinic feldspar included between the principal crystal faces 001, 100 and 010. The lines which cross each other on the faces 001 and 100 indicate the external striations due to the albite and pericline types of polysynthetic twinning; those that appear on the face 010 represent the external striations due to pericline twinning. In the various plagioclases the latter make different angles with the basal

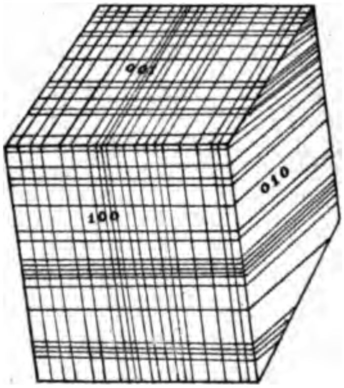

Fig. 9.—External Albite and Pericline bands.

cleavage or with the edge 001:010. In albite it is about as shown in the figure, viz., 13° to 22°; in oligoclase it is 4°; in andesine it is 0°; in labradorite from 2° to 9° in the opposite direction, and for anorthite it is 18° in the same direction as for labradorite (fig. 16.)

When the polysynthetic twinning, albite or pericline, is again enveloped by a Carlsbad twinning, a thin section manifests it by the occurrence of two pairs of bands on one side which extinguish or polarize in sympathetic alternation, differently from two pairs of bands on the other side. Generally the darkened line which separates the Carlsbads can be seen. It is heavier than the other dark lines, and is apt not to agree with them strictly in direction, or to be otherwise irregular.

The twinning of anorthoclase and microcline is characteristic. They combine the albite and pericline types, producing a rectangular quadrillage on all sections of the zone 001:100, except on that which is parallel to the plane of association for the pericline law, and on all sections in the zone 001:010 except on that parallel to the face of association for the albite law. In other words, the section parallel to 010 is identified by the disappearance of the albite macle and that parallel to the plane of association of the pericline macle by the disappearance of the pericline marks. This last plane in anorthoclase, shown by the trace of its macle, makes an angle of —78° to —75° with the edge 001:010. It hence makes a large angle with the base 001, and it is practically perpendicular to the

FIG. 12.—Quadrillage of Microcline.

face 010. In microcline this plane, while nearly perpendicular to 001, and quite perpendicular to 010, has a trace on 010 which forms an angle of —80° to + 100° with the edge 001 : 010 (fig. 16). Its position is between the faces 100 and 201. The cross-hatching of microcline is represented by fig. 12. That of anorthoclase is less distinct, being extremely fine and badly defined.

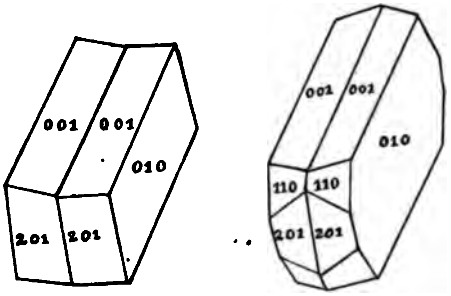

FIG. 13. FIG. 14.

Albite Twins of Labradorite.

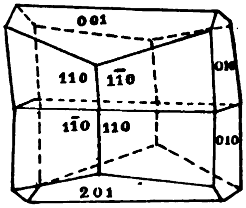

FIG. 15.—Pericline Twins of Albite.

With the plagioclases, properly so called, the albite and periclinic types of twinning play an important rôle (figs. 13, 14, 15). They are adopted as characteristic and permanent standards from which are measured other optic phenomena.

The striations of the pericline macle, when visible in a section parallel to 010, make different angles with the basal cleavages which are visible in the same section, according to the feldspar examined. This angle varies from 0° for andesine, to —18° for anorthite, in one direction and in the other direction it varies to + 13° and + 21° for albite. It may be represented for all the triclinic feldspars by the diagram below (fig. 16), which shows the face 010 of a simple crystal.

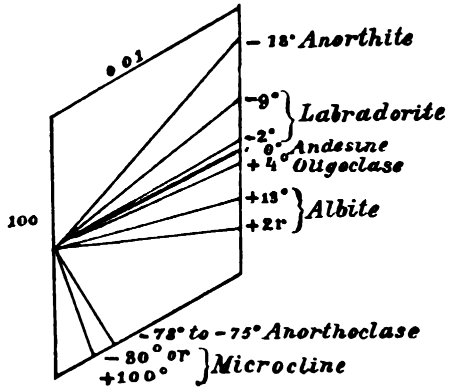

FIG. 16.—Angles of the Pericline Bands on 010.

The plagioclases are also subject to twinning on the Carlsbad, Manebach and Baveno plans, and albite also on the Roc Tourné plan. This last consists of two albite macles, again twinned as couples by the union of the reëntrant angle formed by the faces $\bar{1}01$, 101, of one, upon the salient angle of the other formed by the same faces. The double crystal thus formed is approximately a parallelogram, flattened parallel to 010, one of the twinned pairs being thinner than the other, as shown by figure 17.

In thin section the twinning lines of albite are fine and far apart, often irregular and interrupted; those of oligoclase are very clear and of very regular widths, one of the systems being much more fine than the other—so fine, indeed, that sometimes it is impossible to perceive the width. In labradorite the lamellæ are equally clear and definite, but the width varies much from one lamella to the other, and in the same lamella (rarely) from one point to another. In anorthite the albite lamellæ are

broad and regular, while those of pericline are very frequently distributed only in certain ones of the albite bands, which they cross at varying angles according to the direction of the plate.

Figure 18 represents a triclinic feldspar crystal with, the albite and pericline striations much amplified, to show their positions and direction for the species albite. The front face, 100, is represented in part, but it is very rarely seen in nature. The prism planes, 110, $\bar{1}10$, obliterate it.

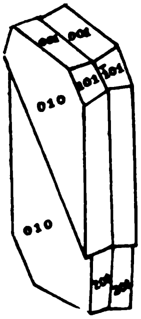

FIG. 17.—Macle of Roc Tourné (Descloizeaux).

Chemical Composition.

According to the law of Tschermak, which is generally adopted as a working hypothesis, at least, the plagioclase feldspars contain such proportions of soda and lime that each can be considered as a mixture of a definite number of the compound molecules Ab and An, in which—

One albite molecule = Ab = $Na_2O.\ Al_2O_3.6\ SiO_2$. or $Na\ Al\ Si_3\ O_8$.

One anorthite molecule = An = $CaO.\ Al_2O_3.\ 2SiO_2$. or $Ca\ Al_2Si_2O_8$.

Thus the basicity grades from albite to anorthite in a somewhat regular series.

Tschermak groups them as follows:*

	Specific Gravity	Compound Molecules.	Percentage of Ab	Percentage of An
Albite.........	2.62	Ab_1An_0 to Ab_8An_1	100.00 to 88.88	0.00 to 11.11
Oligoclase.....	2.64	Ab_6An_1 to Ab_2An_1	85.71 to 66.66	14.28 to 33.33
Andesine......	2.65	Ab_3An_2 to Ab_4An_3	60.40 to 57.14	40.00 to 42.86
Labradorite ...	2.69	Ab_1An_1 to Ab_1An_2	50.00 to 33.33	50.00 to 66.66
Bytownite.....	2.71	Ab_1An_3 to Ab_1An_6	25.00 to 14.28	75.10 to 85.71
Anorthite.....	2.75	Ab_1An_8 to Ab_0An_1	11.11 to 0.00	88.88 to 100.00

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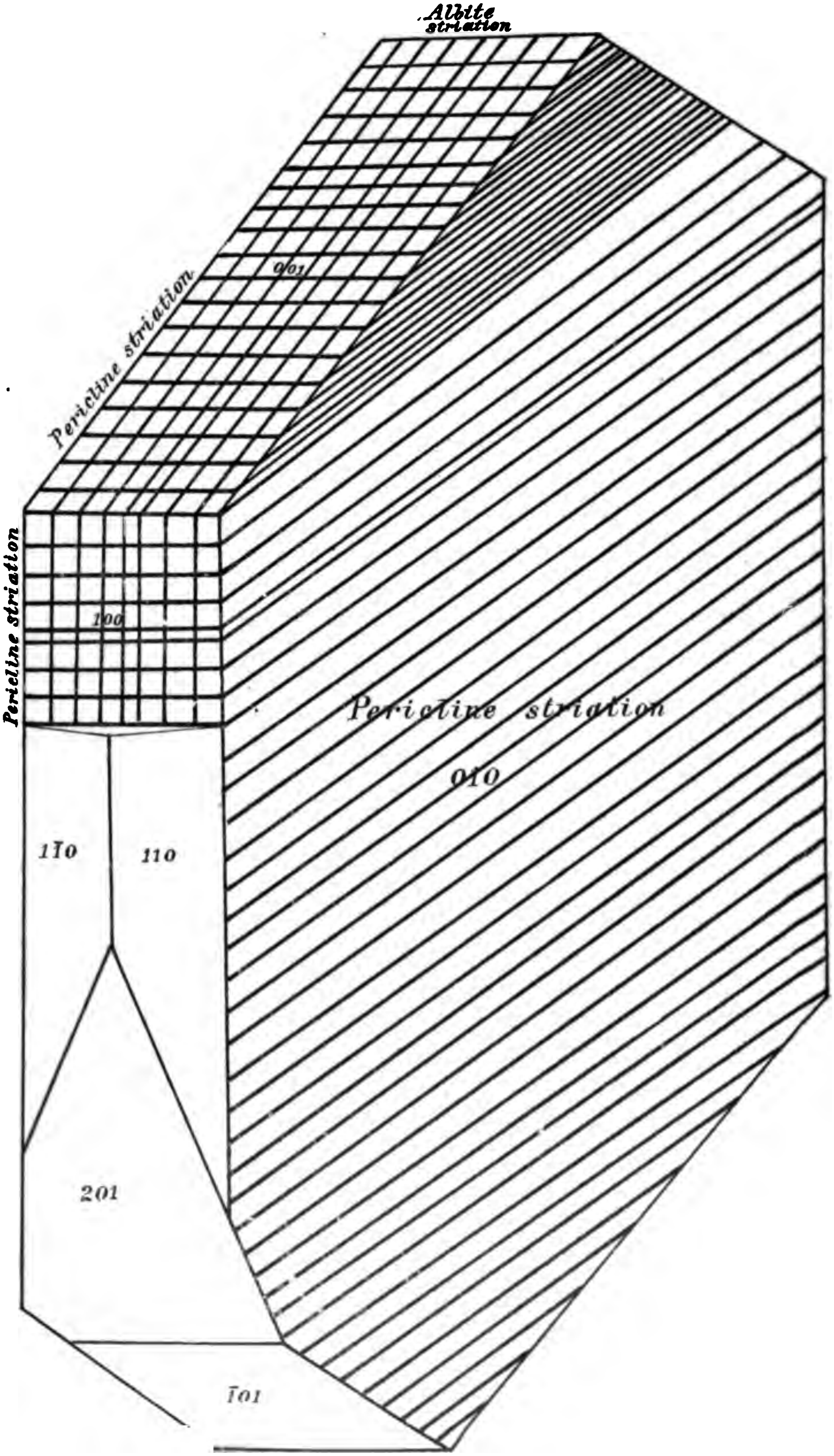
*Minéraux des Roches, p. 196.


Albite striation
Pericline striation
001
Pericline striation
100
Pericline striation
010
1̄10
110
201
1̄01

As a family the feldspars grade, therefore, according to their alkaline base about as follows, from potash to lime:*

SPECIES.	BASES.			Oxygen. Ratio.
	Potash.	Soda.	Lime.	
Orthoclase	dominant	accessory	....	1:3:12
Microcline	dominant	accessory	....	1:3:12
Anorthoclase......	⅓	⅔	traces	1:3:12
Albite............	traces	dominant	....	1:3:12
Oligoclase	traces	⅝	⅜	1:3:10 to 1:3:9
Andesine.........	traces	$\frac{3}{6}$ to $\frac{1}{6}$	[illegible] to [illegible]	1:3:8
Labradorite	traces	¼	¾	1:3:7 to 1:3:6
Bytownite	traces	⅙	$\frac{4}{6}$	1:3:5
Anorthite.........	traces	....	dominant	1:3:4

Thus grouped according to their varying acidity, they are found to vary in general, in a similar continuous order, in their physical and optical properties.

Albite, oligoclase and andesine are not affected by acids, except by hydrofluoric acid; labradorite is attacked after long treatment, while anorthite is easily decomposed. The surface of the microscopic preparation, free from Canada balsam, is treated for several hours at a temperature not exceeding 40° (centigrade) in order to avoid melting the Canada balsam on the other side by which it is adherent to the glass slide; anorthite leaves a skeleton of silica, while labradorite only shows a partial corrosion. The test can be made on a fine powder, and greater heat applied, even to boiling of the acid. The partial attack on labradorite can be made apparent by applying to the slide, after thorough washing in water, some aniline color (as malachite green) which will permanently color the gelatinous silica.

Optic Characters.

In the study of the feldspars it is frequently necessary to indicate the position of a right line situated in the plane 001 or in 010. In order that such designation may be free from ambiguity it has been suggested by Max Schuster that the directions of such line shall be uniformly referred to the edge 001 : 010, with the crystal in the conventional position, i. e., with the vertical axis perpendicular, whether in the plane 001

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*Compare: Cours de minérologie, De Lapparent, p. 403.

or in 010. The angle in the brachypinacoid which the line of extinction, for example, makes with the edge is called positive if the direction of the line is included in the obtuse angle formed by the edges 001 : 010, 010 : 100, and negative if its direction lie in the acute angle of these same edges. The same rule is applied for a line lying in the base 001. Figure 19 represents a simple plagioclase crystal with lines drawn in the faces 001 and 010, with their directions expressed according to Schuster. Figs. 20, 21 and 22 represent faces and sections that may arise in the application of this rule.

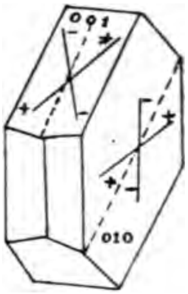

Fig. 19.—Optical signs of the extinction angles according to Schuster's rule.

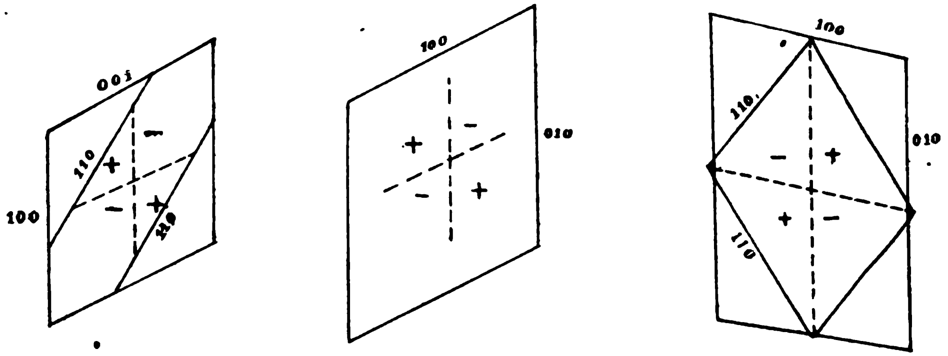

Fig. 20.—Plane 010. Fig. 21.—Plane 001. Fig. 22.—Plane 001.

Illustrations of the sign of the extinction angle according to Schuster's rule.

The principal element is the optic plane. In it lie the optic axes and the bisectrices. Its position in the crystal has definite relations to the cleavages, the external faces and the crystallographic axes in the different feldspars, and its angle with the albite twinning, in the plagioclases, is the key which furnishes

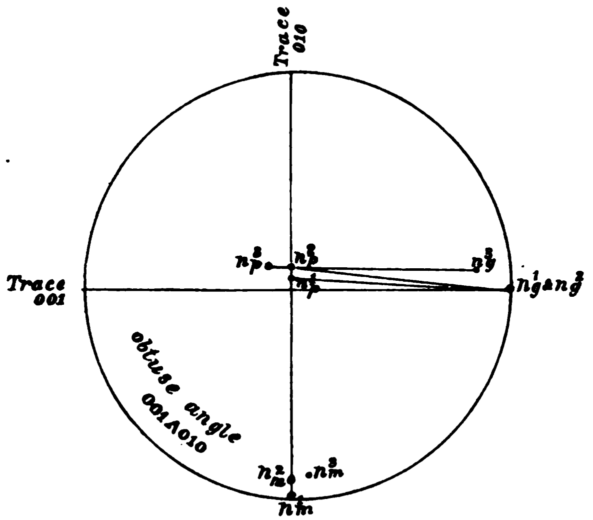

FIG. 23.—Projection of the principal indices of Orthoclase (n^2), Anorthoclase (n^1) and of Microcline (n^3) on the plane perpendicular to the edge 001 : 010.

one of the principal diagnostics. Its position is best expressed, summarily, by projections on the plane perpendicular to the edge 001 : 010. Figure 23 shows the comparative positions of the optic plane in orthoclase, anorthoclase and microcline, as given by Michel-Lévy and Lacroix.* It appears that in these potash feldspars the axial plane is nearly parallel to the base 001, and consequently agrees substantially with the direction of the easy cleavage. It appears also that the axis of least elasticity (n_g, c) is nearly or quite perpendicular to the face 010, the axis of greatest elasticity (n_p, a) lies in the plane 010 and nearly parallel to the base, varying in microcline 5° into the acute angle, and the axis of mean elasticity perpendicular to 001, except in microcline, in which it varies from 3° to 5° from perpendicularity.

In a few sanidines (a glassy form of orthoclase peculiar to lavas of Mesozoic or later date), the axial plane is perpendicular to the easy cleavage, in which case the axes n_g and n_m mutually change places. Such orthoclase is distinguished by Michel-Lévy as orthose déformé.

In the soda-line feldspars the position of the optic plane is

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*Minéraux des Roches, p. 192.

more varied. It is represented in figure 24 as projected on a plane perpendicular to the edge 001 : 010, the bisectrix n_p, being perpendicular or at least less inclined to the surface of the projection than n_g, and n_g lying approximately in the paper. From this it appears that from albite to anorthite there is a gradual rotation of the optic plane in a direction opposite to the movement of the hands of a watch about a line parallel (or nearly parallel) to n_p, and that the whole movement amounts to somewhat less than three-fourths of an entire revolution.

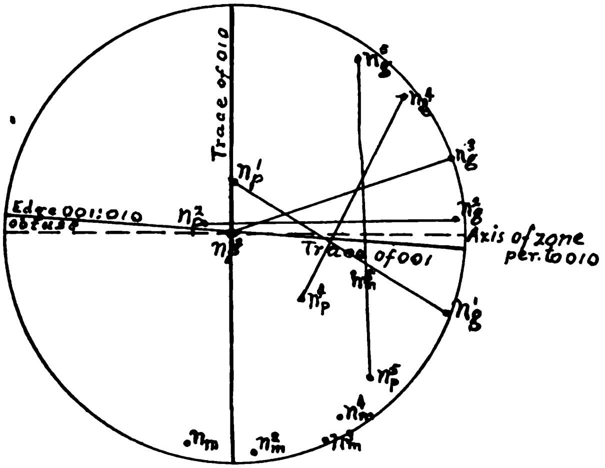

FIG. 24.—Projection of the principal indices of the triclinic feldspars upon a plane perpendicular to 001 : 010. 1, Albite: 2, Oligoclase; 3, Andesine 4, Labradorite; 5, Anorthite.

The optic plane is represented in figure 25 as projected on the face 010. From this it appears that its projection rotates in a similar manner, from this point of view, about a line nearly parallel to n_g. The axis of least elasticity (n_g) of all the plagioclases is situated nearly in the plane perpendicular to the edge 001 : 010, while the axis of greatest elasticity, n_p, is nearly parallel to that edge, and in the plane of symmetry.*

The value of the acute optic angle (2 V), in the various feldspars, and their optical signs, are shown in the following table:

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*There is no zone of symmetry in the triclinic feldspars; but for convenience of reference the zone perpendicular to the edge 001:010 is called the zone of symmetry in the discussion of the plagioclases.

	2V	*2E*	*2H*	*Sign*
Orthoclase	69°	119° to 125°		—
Microcline	88°*		88°	—
Anorthoclase	45°	65° to 75°		—
Albite	77°	155°	80° to 85°	+
Oligoclase	88°		90°	±
Andesine	88°		90° to 100°	—
Labradorite	77°		85° to 89°	+
Anorthite	77° 30′		85°	—

Refraction and Double Refraction.

The feldspars all possess low refraction and double refraction, both being about the same as for quartz. By these characters, therefore, it is sometimes difficult to distinguish them, when pure, from quartz. When other diagnostics are not available resort may be had to the Becke method of distinction† of comparative refraction. This consists in the following very delicate process:

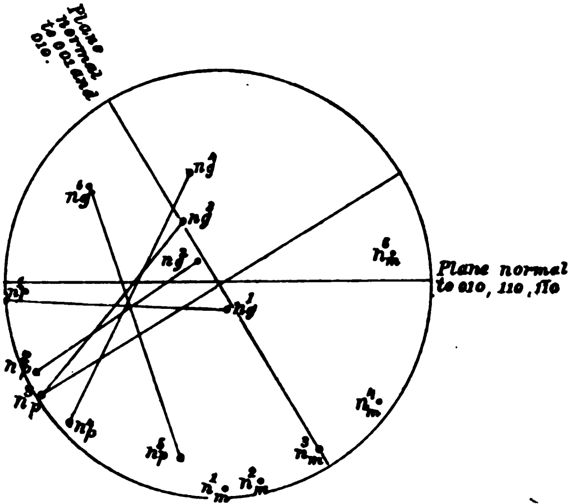

FIG. 25.—Projection of the principal indices of Albite (n^1), Oligoclase (n^2), Andesine (n^3), Labradorite (n^4), and Anorthite (n^5), on the plane 010.

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*The values of 2 V from microcline to anorthite inclusive are taken from Fouqué, Bul. M. Soc. France, 1894, p. 428.

† Uber die Bestimmbarkeit der Gesteinsgemengtheile auf Grund ihres Lichtbrechungs Vermögens. Wien. Acad., 1893, I.

In convergent light with a high power (Nachet No. 7 objective), bring the focus directly upon the line of separation between a quartz grain and a feldspar. On lowering the condenser and removing the analyzing nicol the field is a little darkened, but a very fine line of white light, clearer and brighter than the grain on either side, accompanies sharply the line marking the contact of the two grains. When the objective is focused so that the line is bright, if the objective be raised very gently, and the least amount possible, this bright line moves a little toward the more refractive mineral before it is extinguished. If the objective be lowered in the same way the white border line shifts a little toward the less refractive mineral. This method is most useful for distinguishing between orthoclase and quartz and between the fresh secondary plagioclases of the crystalline schists and quartz. The other feldspars are usually distinguishable by other characters. It is to be employed with one condition, viz: when two adjacent minerals of nearly the same refractive index happen to be cut, one perpendicular to n_p and the other to n_g, the movement of the line might be governed by the difference between n_p and n_g of the minerals, rather than by the difference of their mean refractive indices.

The table below shows the indices of refraction and the double refraction of the feldspars as given by Lévy and Lacroix (Min. des Roches, p. 323):

	Refraction.			Double Refraction.
	n_g	n_m	n_p	$n_g - n_p$
Orthoclase	1.526	1.523	1.519	0.007
Microcline	1.529	1.526	1.523	0.006
Anorthoclase	1.530	1.529	1.523	0.007
Albite	1.540	1.534	1.532	0.008
Oligoclase	1.542	1.538	1.534	0.008
Andesine	1.556	1.553	1.549	0.007
Labradorite	1.562	1.557	1.554	0.008
Anorthite	....	1.566	....	0.013
Quartz	1.553	....	1.544	0.009

METHODS OF DETERMINATION.

(*a*) *Extinction on the Base and Brachypinacoid.*

Schuster and Mallard[*] established the relations existing between the extinction angles on the base and the brachypinacoid, and the changing acidity of the plagioclases. The prevalence of favorable cleavages renders it a simple matter to obtain plates parallel to these faces. For purposes of determination it is usually necessary only to make a coarse powder from one of the crystals, from which may be selected such cleavage fragments as affords these two directions. These may be distinguished not only by the difference in the facility of the cleavage, but also by the different interference figures given in convergent light. Cleavage pieces parallel to 001 will appear larger and more abundant than those parallel to 010. They will be apt to show some trace of the albite striations, and they will never show a bisectrix, but instead will exhibit the indefinite extinction characteristic of n_m. Anorthite comes nearest to exhibiting a bisectrix in a basal section. On the contrary cleavage fragments parallel to 010 are likely to have two straight parallel edges, caused by the easy basal cleavage. These, however, should not be confounded with the basal fragments bounded by the prismatic cleavages. At the same time if the fragments be parallel to 010 they invariably reveal a bisectrix n_g, either perpendicular or somewhat inclined to the axis of the microscope when examined in convergent light. To this statement labradorite (from Ab_1 An_1 to Ab_1 An_6) may be considered an exception, inasmuch as the inclination of the axis (n_g) is so great that the point at which it pierces the plane of the section is outside the field of the microscope. It may still be distinguished from a basal section which gives the same black bar by the application of the quartz of sensitive tint, which shows the lowering of color characteristic of the bisectrix n_g although not so decidedly as when the axis is exactly perpendicular. In a similar manner the black bar seen in labradorite in a basal section may be shown to be associated with n_p. The basal section of

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[*] Über die optische Orientirung der Plagioclase. Min. u. Petrograph. Mitt., Tschermak, 1880, III, 117-284.

Sur l'isomorphisme des feldspaths tricliniques. Bul. Soc. Min., France, 1881, IV, p. 103.

anorthite shows the black bar associated with n_g. Compare also the page following—"Means of discovering sections parallel to 010."

When the examination has to do with the microlitic feldspars of the second consolidation, it is usually impossible to obtain cleavage fragments for the foregoing process. It is then necessary to search for favorable sections cut at random in a thin section of the rock, when the same distinctions are to be observed, or resort may be had to the methods mentioned below. Sections parallel to 010 do not show the albite twinning lines.

In general, when the extinction angles on both 001 and 010 are large that fact indicates bytownite or anorthite. When both are small the feldspar is either oligoclase or andesine. Intermediate extinction angles are seen in albite and labradorite; while the potash and soda-potash feldspars have extinction on 001 practically parallel to the cleavages (except microcline, which has extinction at 15° 30′), and on 010 their extinction varies from 5° to 9°.

Following are the extinction angles of the feldspars on the base and brachypinacoid:

	Extinction on 001.	Extinction on 010.
Orthoclase	0°	+5° to 7°
Microcline	+15°30′	+5° 30′
Anorthoclase	+2°	+9°
Albite	+4°	+19°30′
Oligoclase	+2°	+8°
Andesine	2°30′	−10°
Labradorite	−5°30′	−20°
Bytownite	15° to 25°	−26° to −32°
Anorthite	36°30′	−41°30′

(*b*) *The Statistical Method.**

The method proposed by Michel-Lévy, often designated the statistical method, is applicable to all cases in which cleavage pieces of sufficient size cannot be obtained, but in which still the albite twinning is evident. Since the albite twinning forms lamellæ parallel to the face 010, whose edges are inclined

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*De l'emploi du microscope polarisant à lumière parallel pour l'étude des plaques minces des roches éruptives. Ann. des Mines, Dec., 1877, pp. 392 to 471 (v. p. 451).

to each other alternately outward and inward, a thin section cutting these lamallæ at right angles to 010 would cut them also at right angles, and the extinction angles on opposite sides of any twinning line would be equal, but of contrary signs since, according to the law of albite twinning, one lamalla is turned 180° from the conventional position about a line perpendicular to 010. In case the section be not cut in a plane perpendicular to 010 the extinction on one side of the twinning line is greater than on the other. The method consists in finding in some feldspar grain the maximum equal extinctions on opposite sides of an albite twinning line. All sections that have equal extinctions on adjacent sides of a twinning line in the same species are cut in the zone perpendicular to the faces 010; but only one of these affords the maximum equal extinction. The position of the plane which affords the maximum extinctions in the zone perpendicular to 010, is different for the different species, and the maxima also differ for the different species. When this maximum has been found it serves for the index to the species according to the following tabulation. The table, drawn principally from

	Composition.	Maximum equal Extinction.	Position of the Plane with respect to the bisectrices.
Orthoclase	Or.	0°	Monoclinic.
Microcline	Or.	+19°	Inclined (25° N. and 25° E.).
Anorthoclase ..	Ab_2Or.	....	....
Albite	Ab	-16°	Perpendicular to n_p in the obtuse angle.
Oligoclase	Ab_3An_1	+4°	Perpendicular to n_p in the acute angle.
Oligoclase	Ab_4An_1	+¾°	Inclined 30° on n_m and 25° from 001, downward toward the front, i. e. S.
Andesine	Ab_5An_3	+16°	Inclined 4° E. and 4° N. from n_p in the acute angle.
Labradorite ...	Ab_1An_1	+27°	Inclined 10° E. and 15° N. from n_p in the acute angle.
Labrador-Bytownite ...	Ab_3An_4	+38°	Perpendicular to 201, i. e. inclined 18° E and 22° N. from n_p in the acute angle.
Anorthite......	An	+52½°	Inclined 180° N. from the optic axis B, and 30° E. from n_p in the acute angle.

the épures of Michel-Lévy,* also expresses the position of the plane with respect to the bisectrices. The maximum extinction angles here given are found, for each feldspar, on the vertical diameters in the plates I—VII.

In the application of this method it is not necessary to examine all sections of feldspars at random, but by certain guides those in the zonal position can be selected. (1) It is the zone of symmetry of the albite twinning, and the alternate lamellæ extinguish at the same angle. If account be taken of the optical sign of the direction of extinction (+ to the right of the twinning line and — to the left) the positions of other planes, inclined to this zone may be identified by reference to the épures of Michel-Lévy (plates I—VII).† (2) The sections of this zone, being perpendicular to the face of association of both the albite and the Carlsbad twinning, the albite twinning lines ought to be extremely fine and straight. Further the feldspathic microlites, however small, cross the thin section perpendicularly. They seem to be elongated parallel to these lines; their outlines are clear and their colors of double refraction are those that comport with the total thickness of the plaque for the orientation in each case. (3) Sections that are perpendicular to 010 have not only equal extinction angles, but they may be identified by the fact that the two lamellæ on opposite sides of the twinning line have, on rotation between crossed nicols eight positions of equal luminosity, viz: four at 45° from the spider lines, one in each quadrant and four at the points of agreement with the spider lines. In these positions the lamellæ appear to belong to the same crystal, being separated only by a very fine dark line. This test is extremely delicate and with the least obliquity to the axis of the zone the equal luminosity does not appear.

This method, notwithstanding its tediousness, is one of the most serviceable as well as the most reliable, owing to the readiness with which sections perpendicular to the plane 010 can be recognized, and to the characteristic differences in the maxima of the various feldspars. The chief obstacles that interfere with its use are (1) the possible existence of two or

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*Détermination des feldspaths dans les plaques minces, first fascicule, 1894.

† For explanation of these plates see p. 40.

more feldspars in the same thin section, and (2) the possible non-existence of the maximum equal extinction in any of the crystals cut by the random section. The former is more likely to arise in the examination of the acid and metamorphic rocks, and the latter in case of a limited number of feldspar sections in the rock cut. In the presence of two or more feldspars, however, usually they will be found to differ in transparency or in mode of distribution, or in other evident optical characters, and the error can be obviated. In case of the feldspathic microlites, they are almost invariably of the same species when formed rapidly at the second consolidation. The second obstacle can only be reduced by increasing the number of feldspar sections subjected to inspection.

These maxima, alone, are sufficient to identify the oligoclases (0° to 5°), the basic andesines (more than 16°, less than 22°), the labradorites (from 22° to 35°), the bytownites (from 35° to 45°), and the anorthites (above 45°).

When the feldspar microlites are twinned on the albite plan, as frequently happens, they are amenable to this process of examination. When they are simple their determination is more difficult. It has been proposed by Michel-Lévy, in that case, to employ the zone 001:010 parallel to the axis of which they have their longest dimension, but the results obtained are not sufficiently characteristic for all the species. Extinctions of such microlites, cut in this zone and referred to their longer dimension, are as follows:

Orthoclase	0° to 5°	Compare p. 43.
Microcline	0° to 16°	
Albite	0° to 20°	
Oligoclase $Ab_4 An_1$	0° to ½°	
Oligoclase $Ab_3 An_1$	0° to 0°	
Andesine	0° to 7°	
Labradorite	0° to 18°	
Labradorite (basic)	0° to 32°	
Anorthite	0° to 55°	

Microcline, some forms of labradorite and albite could hardly be distinguished by their maximum extinctions in simple microlites, but orthoclase, oligoclase and anorthite are characterized by maxima which are sufficiently distinct. Microcline, however, is rarely or never seen in the condition of microlites, while the associations of labradorite and albite

are so different that there is little danger of confounding them. Labradorite is the commonest product of the consolidation of the basic eruptives and albite almost invariably results from metamorphism, frequently from the contact of igneous rocks on the calcareous clastics.

There is very little reason to expect, side by side, microlites of different natures. In the vast majority of cases the microlites are formed rapidly, and present a great preponderance of a single species of plagioclase.

(*c*) *Sections Perpendicular to the Bisectrices.*

This method of determination requires the use of convergent light and the careful observation of the interference figure of the axis of elasticity. It is well, also, but not always necessary, to place a drop of iodide of methyl, or of glycerine, on the lens of the objective, and another on the upper lens of the condenser, in order that when they are both brought near the slide holding the section, the liquid will spread to the right and left, producing practical immersion. This increases the field of possible observation without deranging the geometric relations.

The details of this method have recently been elaborated by M. Fouqué,* who has confirmed it by a great number of illustrations, and by chemical analyses. It may at first sight appear to be a difficult task to obtain sections perpendicular to the bisectrices n_g or n_p. But when it is remembered that cleavage pieces or sections cut parallel to 010 will nearly always show the axis n_g, and when not perpendicular may be made so by a little oblique grinding or by the use of the tilting stage of Federov constructed by Nachet, and also that the axis n_p is in the vicinity of the edge 001 : 010, it is evident that but little manipulation is necessary to cut a crystal perpendicular to either axis. Small transparent crystals are necessary, or pieces of larger crystals bounded by known cleavages. The little crystal is encased in a ball of thick Canada balsam which can be moulded at will. This is allowed to swim in a Balsam more liquid, enveloped in a little glass ring. Observed thus in convergent polarized light the crystal is brought to

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*Contribution à l'étude des feldspaths des roches volcaniques. Bul. Soc. Min. France, Vol. XVII, 1894, pp. 283-611. Also issued separately with independent paging.

present the orientation in which it gives the figure of the axis sought. The operation is facilitated by the previous knowledge of its cleavages, and of the probable nature of the species in hand.

The axis n_p is preferable in the examination of the acid plagioclases, and n_g in that of the basic. M. Fouqué ascertained by the examination of numerous inclined sections that, in case of slight obliquity, the decentring of the image and the consequent error in the result, is less in sections perpendicular to n_p than in those perpendicular to n_g. He also ascertained that the error is greater (except in the basic feldspars) when the inclination is in the direction of the trace of the plane of the optic axes than in a direction perpendicular to it. An inclination of 5° removes the figure one-third of the radius of the field of the microscope away from the central position. An inclination of 10° removes it two-thirds of the same radius.

If a bisectrix is exposed favorably in the field of the microscope, as frequently happens in a rock section cut at random, it is important to know whether it is n_p or n_g. Resort may be had to the quartz of sensitive tint, which with the feldspars in sections not over 0.03mm in thickness, is the most ready and reliable test. It is also possible to know whether the axis so examined is in the acute or the obtuse angle. After some experience the observer becomes able to judge by the appearance of the interference figure, and its changes on rotation of the stage, in nearly all cases, whether the axial angle is acute or obtuse. Thus, in the first place, the sections perpendicular to n_p are more dark in parallel polarized light than those perpendicular to n_g. This observation is frequently sufficient, at least if the angle 2V does not exceed 80°. The delicacy of the observation is increased by interposing a quartz plate which gives the rose color of the first order of the color scale. Again it is frequently possible to judge whether the axial angle under examination is acute by noting the comparative amount of rotation of the stage necessary to produce a marked separation of the hyperbolas. The promptly separating hyperbolas belong to the obtuse angle. When the hyperbolas are tardy in moving from the black cross the angle is acute. In case such rough observation be not sufficient, the hyperbolas may

be brought to the position of tangency at the margin of the field of the microscope, first on one bisectrix and then on the other. In each case the amount of rotation is noted in degrees at the margin of the platine. That which requires the greater amount of rotation to produce tangency is the axis of the acute angle. Finally, when there remains uncertainty whether the angle is acute or obtuse, it may be measured by the use of the axial goniometer already described in the AMERICAN GEOLOGIST.*

Once the interference figure is well centered and the angle known, it remains to measure the extinction angle with a trace of a known crystallographic character. This angle is that made by the axial plane with a twinning (albite) lamella, or with the cleavage parallel to 001. Sections perpendicular to n_p are always measured, for this angle, on the albite twinning, or, which is the same thing, on the cleavage 010. In the case of sections perpendicular to n_g the same crystallographic character is employed in examining the basic feldspars, but it is necessary to have recourse to some other character for the acid feldspars in which the plane perpendicular to n_g is parallel, or nearly parallel, to the face 010, rendering the cleavage (010) and the albite macle invisible. In that case extinction is measured on the cleavage parallel to 001, which is very rarely wanting in the acid feldspars. In all the lime-soda feldspars, except albite and anorthite, the sections parallel to 001 and 010, and perpendicular to n_g, appertain practically to the same zone. For these feldspars the extinction angle upon a section perpendicular to n_g has therefore the same value, whatever be the cleavage, that of 001 or that of 010, which is chosen for the measurement of extinction.

The measurement having been taken, reference may be made to the following table, given by M. Fouqué as a summary statement of the results of all his work. The beginner may be warned against the liability of misreading the extinction angle, thus getting the complement of the extinction angle given in this table. In that case his error consists in measuring, not from the trace of the axial plane, but from a line perpendicular to it. In other words—the axial plane, i. e., the position of extinction, should be made to coincide with the

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*Op. cit., Vol. XVII, p. 79.

vertical thread of the nicol—not with the horizontal—and the rotation from that position towards the right, necessary to bring the cleavage or the albite macle into agreement with the same thread, is the angle of extinction desired.

Extinctions which range from 55° upward to 88° indicate the bisectrix n_p Those which occur between 48° and 3° indicate n_g perpendicular to the section.

(*d*) *Sections Perpendicular to the Axis of Mean Elasticity*, n_m.

M. de Federov has studied the extinctions in sections perpendicular to the axis n_m. They present the highest colors between crossed nicols, and a somewhat characteristic figure in convergent light.

As shown by the general épures they vary, from albite to andesine inclusive, from +2° to —2. They are not, therefore, sufficiently characteristic to separate the acid andesines from the albites. The basic feldspars, on the contrary, ranging from —2° (Andesine, $Ab_5 An_3$) to —10° for labradorite, and to —36° for anorthite, are susceptible of distinction in these sections. It appears, therefore, that very diverse methods succeed in this basic series and generally fail in the acid series. Still the sections of maximum biréfringence are capable of rendering service, especially in the absence of twinning.

(*e*) *Sections Perpendicular to the Optic Axes.*

M. de Federov has also given the extinction angles on the optic axes in simple crystals (1′); and to these Michel-Lévy has added those of twinned crystals, both those of the Carlsbad type and those of the albite. The numerals (1) and (1′) are made to represent the two individuals of the albite twinned crystal, and (2) and (2′) the two adjacent albite individuals of a Carlsbad-twinned crystal. It is evident that the parts (1) and (1′) belong to one or the other of the parts (2), (2′). The following table gives the extinctions on the axis (A). Columns (2) and (2′) and column (1) are added by Michel-Lévy. The former shows the extinctions on the individuals (2) and (2′), and the latter the angle of the plane of the optic axes with the trace of the cleavage 010, which can easily be obtained from the figure in convergent light.

SPECIES OF THE FELDSPARS.	Specific Gravity	Content of Silica.	Angle of 001 with a section perpendicular to n_g	2V	Acute bisectrix.	Dispersion about n_p	Angle of extinction on a section perpendicular to n_p	Angle of extinction on a section perpendicular to n_g	Mean index.	Angle of the traces of the macles of albite and of pericline on a section perpendicular to n_p	Angle of extinction on 001.	Angle of extinction on 010.
Anorthite..............	2.745	44	35°	77° 30′	n_p	$\rho < v$	55° 30′	48°	1.582	65°	—36° 30′	—41° 30′
Bytownite.............	2.725	......	......	......	n_p	$\rho < v$	57°	42°	......	......	....	....
Labrador-Bytownite....	2.705	54	49° 30′	77°	n_g	$\rho < v$	58° 30′	33°	1.563	78°	—11°	—25°
Labradorite............	2.696	55	53°	77°	n_g	$\rho < v$	60°	22°	1.558	82°	— 5° 30°	—20°
Andesine..............	2.675	58	68°	88°	n_g	$\rho > v$	66°	9°	1.553	85°	— 2° 30′	—10°
Andesine-Oligoclase....	2.654	62	74°	86°	n_p	$\rho > v$	75°	3°	......	......	— 2°	— 4°
Oligoclase.............	2.645	64	......	88°	n_p	$\rho > v$	88°	5°	1.542	......	+ 2°	+ 8°
Oligoclase-Albite........	2.640	65	87°	88° 30′	n_g	$\rho > v$	84° 30′	10° 30′	......	......	+ 2° 30′	+10° 30′
Albite.................	2.610	68	78°	77°	n_g	$\rho > v$	74°	19° 30′	1.534	......	— 4°	+19° 30′
Anorthoclase..........	2.580	68	......	45°	n_g	$\rho > v$	88° 30′	9°	1.528	......	+ 2°	+ 9°
Microcline-Anorthoclase	2.570	......	......	60°	n_p	$\rho > v$	88° 30′	7°	......	......	....	....
Microcline.............	2.560	65.5	81°	88°	n_p	$\rho > v$	88°	10°	1.526	......	+15° 30′	+ 5° 30′

	(1)	(1')	(2)	(2')	Notes.
Albite...............	A+62°	+37°	+30°	+28°(1)	(1) Near the
Oligoclase (Ab_4An_1)..	A 90°	0° (2)	+25°	—25°	axis B.
Oligoclase (Ab_3An_1)..	A—82°	—40° (2)	+22°	+22°	
Andesine............	A—71°	—48° (2)	+15°	+35°	(2) Near the
Labradorite (Ab_1An_1).	A—49°	—40°	+10°	+27°	axis A.
Anorthite............	A—20°	—53°	—25°	+15°	

For the optic axis (B) the following table gives the same elements. It is constructed in part from the numbers of the general épures of Michel-Lévy:

	(1)	(1')	(2)	(2')	Remarks.
Albite...............	B+63°	+40°	+45°	—32°	(1) Near the
Oligoclase (Ab_4An_1)..	B 90°	90° (1)	—35°	—25°	axis A.
Oligoclase (Ab_3An_1)..	B—82°	—42° (1)	—17°	—16°	
Andesine............	B—69°	—31° (1)	— 6°	0°	(2) Near the
Labradorite (Ab_1An_1).	B—57°	—23°	+ 3°	+14°	axis B.
Anorthite............	B—62°	—12° (2)	+47°	—56°	

(*f*) *The Use of Zonal Sections.*

Michel-Lévy has investigated the principal crystallographic zones of the feldspars, and has deduced the characteristic extinction angles in each. These zones are the following:

1. Zone perpendicular to 010.
2. Zone normal to the edge 100:010 situated in 010.
3. Zone parallel to 100:010.
4. Zone parallel to 001:010.

The examination of the zone perpendicular to 010 is already described under the *Statistical Method.* (p. 30). With this as a basis Michel-Lévy has constructed a series of very ingenious and complicated tables, represented graphically in the plates (épures) for the various plagioclases (plates I, II, III, IV.V, VI and VII). These circular plates show not only the maximum equal extinctions of the simple crystal in each plagioclase, when cut in a plane perpendicular to 010, but also the extinctions of the same when cut in any zone whose axis is in 010. The former is shown by the highest number seen along the vertical diameter of each plate, and the latter

by the figures at the intersections of the meridians and the parallels. Any line situated in 010 may, hence, be taken as the axis of a zone, and sections cut in that zone will show the extinctions expressed on its principal meridian for the feldspar considered.

These plates are stereographic projections of the sections of the several plagioclases perpendicular to the prism. The poles of the various planes of this prism are in the circumference. The pole of the base (001) is not far from the center, in the lower right-hand quadrant. The poles of some other planes are also expressed. The entire surface is divided by the meridians and parallels into quadrangular areas having arcs of five degrees. The meridians running from right to left all pass through the poles 010. The parallels which surround the poles are the various stereographic positions of planes inclined in different degrees to 010 at intervals of 5°, but in the zone whose axis is perpendicular to the vertical axis *c* and parallel to 010. These elements are represented by the fine black lines as meridians and parallels, and are the same for all the plagioclases. The trace of the optic plane is shown by the heavy black line passing through the loci of the optic axes A and B and the bisectrices n_g and n_p. The other heavy lines show the planes connecting n_m with the bisectrices. About the axes of elasticity are double curves in broken lines. These unite the poles having the same double refraction. About the optic axes the first curve shows the double refraction 0.25. Then comes the curves of 0.35 to 0.85. This last surrounds the mean axis of elasticity n_m. At the principal intersections of the meridians and the parallels are figures which give, in degrees, the angles of extinction for the planes whose poles are at those intersections. They are counted from 0° to 90° and are + on the right of the trace 010 (the albite line), and — on the left, as indicated. The observer is supposed to be placed above the épure perpendicular to each radius of the hemisphere, his body parallel to the trace 010; that is to say, to the parallels, his head higher than his feet for the lower semicircle, but lower for the upper semicircle. The emergence of the optic axes is at A and B. The axes of elasticity n_g, n_m and n_p pierce the great sphere at the points expressed for each feldspar. They are united by great

circles in black which show the planes of principal elasticity. The fine dotted lines unite poles of the same extinction angle. The curves composed of crosses separate the negative from the positive extinctions, and coincide with the curves of 0° extinction.

The various planes of an inclined zonal axis contained in the face 010 would find their poles arranged on an arc of a great circle which would cross the plate along a meridian extending between the poles 010. The numbers that are seen along this meridian denote the extinction angles for the different planes of such zone. The greater the inclination of the zonal axis the greater the separation of its meridian from the horizontal diameter of the épure.

These épures represent the projection and the optical characters of simple crystals or lamellæ in the conventional position. In the case of polysynthetic albite twinning the extinction of every alternate lamella is of a negative sign, if read according to Schuster's rule, but such negative reading would not be that expressed on these épures. This change of sign is owing to the rotation of the albite macle 180° about an axis perdendicular to 010. Again in the case of the Carlsbad twinning in which there is a rotation of 180° about a line parallel to the vertical crystallographic axis, it is evident that two individuals have contrary signs for the same reason. In the case of both Carlsbad and albite twinning in the same compound individual, only one albite lamella and its homologues occupy the conventional position, although several may extinguish at the same point.

The zone normal to the edge 100:010 situated in 010 has all its poles in the horizontal diameter of the épures already referred to. The maximum extinction is always in the vicinity of 010, and it increases regularly from a point near the edge 100:010, as below. This zone is very characteristic for the acid feldspars if the study is not carried to sections beyond an inclination of 50° with the section perpendicular to the prism. It affords a distinction between albite and andesine, and also separates the oligoclases.

It appears, therefore, that the increments are continuous from albite to anorthite, and this zone would be most charac-

teristic and the most convenient if its sections could be found easily.

	Absolute Maximum.	Extinction at 50° from 100 : 010.	
		At the left.	At the right.
Albite	6°	+4°	−2½°
Oligoclase Ab_4An_1	20°	+12°	−10½°
Oligoclase Ab_3An_1	25°	+13°	−13°
Andesine Ab_5An_3	34°	+17½°	−22½°
Labradorite Ab_1An	52°	+19°	−37°
Anorthite	90°	+30°	−79°

Zone Parallel to 100:010.—This zone furnishes sections which are not altogether conclusive, especially for the determination of the acid plagioclases, whose extinctions vary too widely. It can be said, however, that in this zone the parts of the Carlsbad twin extinguish symmetrically. The same is true of the lamellæ of the albite twinning. All its poles are found in the exterior circle of the épures.

Zone Parallel to the Edge 001:010.—This zone, parallel to the two easy cleavages, is in constant application in the variolytes, in arborescent forms of plagioclase, and in crystallites formed rapidly. Such are, indeed, elongated parallel to 001:010. The normal alongement of orthoclase, when fibrous, is parallel to 001:010, as shown by numerous spherulytes of the orthophyres and of basic microgranulytes.*

The spherulytes of the plagioclases do not offer a single known exception to the above rule. (Michel-Lévy.)

The extinction numbers belonging to this zone are ranged on the meridian which passes through the poles 001 and 010, at about 26° below the plane perpendicular to the face 010 and to the edge 100:010. The following are in its numerical properties: (p. 43).

There might arise uncertainty between the albites and the most basic andesines. The smallest extinctions appertain to the oligoclases and the acid andesines. From labradorite proper the maximum angle of extinction quickly exceeds the maximum extinction applicable to the albites. It is worthy of

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*"It is quite exceptional that Williams and Iddings have encountered spherulytes of orthoclase whose fibres are elongated parallel to 100:010."

Albite	Between 001 and the obtuse angle 001∧010.	0°–20°	Near 010.
Oligoclase Ab_4An_1.		0°–½°	Between 001 and 001 ∧010 acute.
Oligoclase Ab_3An_1.	.	0°–0°	
Andesine	Near 001, between 001 and the obtuse angle 001∧010.	0°–7°	In 010.
Labradorite	Between 001 and 001∧010 obtuse.	0°–18°	Near 010. Between 001 and 001∧010 acute.
Labradorite (basic)	Between 001 and 001∧010 obtuse.	0°–32°	Near 010. Between 001 and 001∧010 acute.
Anorthite	Between 001 and 001∧010 obtuse.	0°–55°	Near 010. Between 001 and 001∧010 acute.

note that the zone 001 :010 always contains a plane nearly perpendicular to the bisectrix n_g. Compare p. 33.

In making use of the crystallographic zones of the feldspars it is evident, therefore, that the zone perpendicular to 010 is the most reliable and has the widest application. When the albite twinning line is visible it alone leads to characteristic results by the shortest, most rapid and easiest way. The task is facilitated and the distinction between albite and certain andesines is assured, when several instances occur of the combination of Carlsbad and albite twinning, which is very frequently the case. The method of the positions of equal luminosity is a convenient means of searching out the different groupings of the twinned lamellæ, as well as the sections properly oriented.

After the zone perpendicular to the brachypinacoid, which is susceptible of universal and almost exclusive use with microlites of small size, the zone 001 :010 affords similar advantages for every case of the variolytes and the porphyrytes, or andesytes, in which plagioclase takes arborescent or spherulitic forms.

The anorthites cannot be confounded with any other feldspar. As to the oligoclases, it should be remembered that their properties are very near those of the anorthoclases. It is convenient then to resort to the determination of the indices of refraction, or to the measurement of the angle of the optic axes, which in the anorthoclases is much smaller about the acute negative bisectrix (p. 27).

(*g*) *Means of Discovering Sections Parallel to 010.*[*]

(Compare p. 29, et suiv.)

The remarkable work of Max Schuster upon the plagioclases,[†] so happily completed by the theoretical application by Mallard,[‡] has brought to light what can be drawn from the extinctions on any face whatever, provided its direction can be determined.

From this point of view the face 010 is the most convenient, because it eliminates the albite twinning characters, and, further, it distributes the extinctions between numbers sufficiently separated. The adjoining diagram (fig. 26) reproduces the curve of Max Schuster, and from that as a datum adds the feldspars from the new épures (plates I-VII).

In order to utilize[§] extinctions in thin sections when the feldspars appear scattered in a section cut at random, it is necessary (1) to know how to recognize sections near 010, and to judge approximately of the error committed by defective orientation; (2) to be able to determine the obtuse angle 001 ∧ 100.

1. *a.* The sections 010 being parallel to the face of the association of the macle of albite, the hemitropic lamellæ and their overlapping edges ought to widen out, and even to disappear at last, at the same time that their extinctions become the same; for the ellipse of the indices returns upon itself after a rotation of 180°. If in a section of the thickness of 0.02mm (e) the overlapping of the two lamellæ reaches, for example, a width (l) of 0.3mm, we should have evidently, calling α the angle which 010 makes with the thin section.

$$\tan \alpha \text{ equals } \frac{e}{l} \text{ equals } \frac{0.02}{0.3} \text{ equals } \frac{1}{15}$$

α is less than 4°. We shall see later the error that would be committed, from this, in the reading of the extinctions.

b. The Carlsbad macle has also for face of association

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[*] Translated from Michel-Lévy. Déter. des Feldspaths, p. 46.

[†] Uber die optische Orientirung der Plagioclase, Tschermak. M. P. Mittheil, 1880, III, 117.

[‡] Sur l'isomorphisme des feldspaths tricliniques. But. Soc. Min. de France, 1881, IV, 96.

[§] Comptes Rendus, 10 Nov., 1890. Bul. Soc. Géol. France, 1890. Réunion à Clermont-Ferrand, Etudes sur les roches des Puys et du Mont Dore.

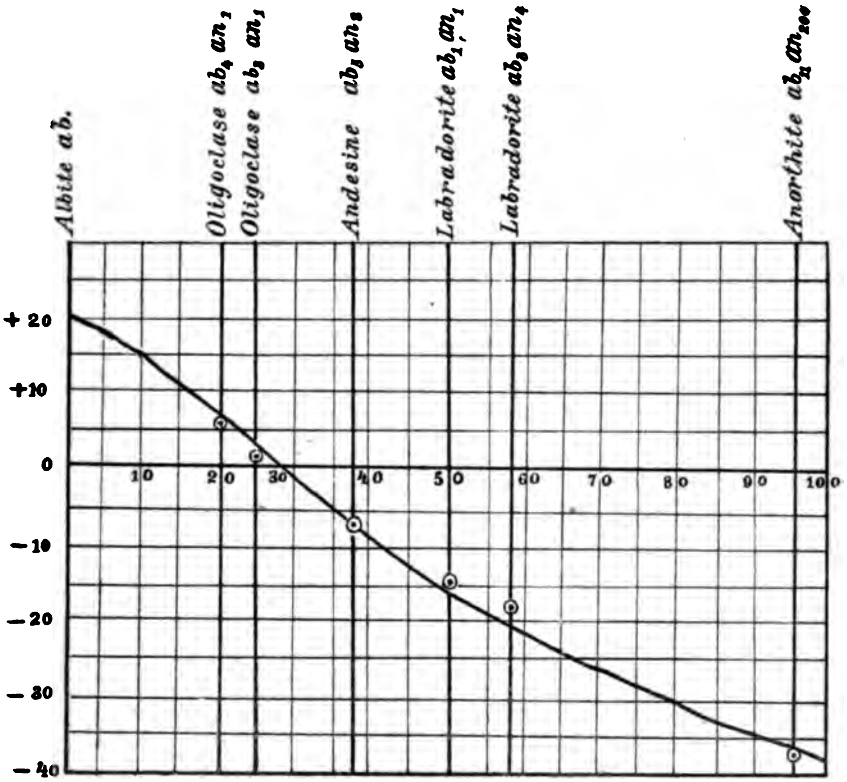


FIG. 26.—Extinctions on 010 referred to the trace of the edge 001 : 010, positive, in the obtuse angle 001∧100. (Michel Lévy).

the face 010. It ought then to disappear in sections parallel to 010, or, rather, it should only be visible by reason of the superposition of two individuals of different optical orientation; for the ellipse of the indices is returned about the edge 100:010, and that of the twin takes a position in 010 which is symmetrical with respect to the direction of 100. In reality, in the case of a Carlsbad twinning, contrary to that of albite twinning, the junction of the twins is not a plane; there is a reciprocal penetration which is often very irregular, and the sections cut, although rigorously parallel to 010, very often show two individuals adjoining and partly superposed—in a word, penetrating each other along a line more or less sinuous and irregular. When the traces of the easy cleavages (001)

are distinctly visible it is necessary that the angle between them be about 128°, but that is a condition which is not sufficient, and which only acquires a true value if the extinctions of the same sign in the two twinned individuals occur symmetrically with respect to the bisectrix of the angle 128°. There is then only one other plane in the zone 100:010 which enjoys the same property. (Fig. 27.)

c. The faces which bound the supposed section parallel to 010 can often be distinguished, sometimes by means of the zones of increment, or growth, and sometimes by evident external contours. These faces are, in order of frequence, 001, $\bar{2}01$, $\bar{1}01$, 110, $\bar{1}10$, 201 and 203. The profile of their angles constitutes a very good verification. Compare Fig. 28 for albite.

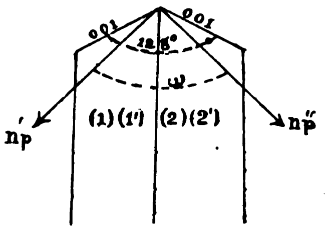


FIG. 27.—Carlsbad macle visible in 010.

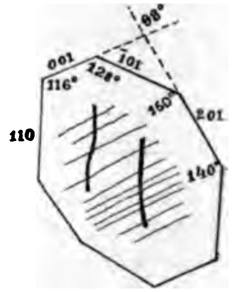


FIG. 28.—Face 010 in Albite.

d. Quite often the cleavage 001 is represented by fine straight cracks, best visible in high powers and by lowering the polarizer. Sometimes there is an excellent verification by cracks more coarse and more visible which are parallel to the cleavages of the prism 110 or $\bar{1}10$.

The discovery of the fine cracks (001) is facilitated by two circumstances: They are always near the negative direction n_p of extinction, since this last oscillates between +20° and —36°. They are often indicated by fine hemitropic lamellæ of the pericline twinning.

e. We have not mentioned, up to the present, this manner of twinning, because, from an optical point of view, it blends closely with the individual (1') (p. 37) of the albite law of twinning; but it relieves all uncertainty as to the face of association which is peculiar to it, for it may be said that, at least for the oligoclases and the andesines, this face is almost

parallel to 001, and it has not appeared to me to depart sensibly from it in labradorite (see Fig. 16). On the other hand, the abundance of lamellæ of the pericline type impairs the diagnostic which might be drawn from the disappearance of the albite lamellæ, especially in anorthite in which the pericline macle sometimes predominates over that of the albite. In anorthite from St. Clement the face of association is about —15° from 001, in the zone 001:100, and in the acute angle 001 $\wedge$ 010.

f. It remains to revert to the images seen in convergent light. The bisectrix n_g is visible in the face 010 in albite, oligoclase and andesine. The oligoclase of the second class ($Ab_4 An_1$) gives a figure almost at the center of the field of the microscope, with an extinction at + 6° in 010.

As the concentric zones of growth of the plagioclases very often attain an acidity in a narrow belt at the periphery which involves the centring of the figure seen in convergent light, it is useful to proceed to this method of verification.

(2). Once the suitable section is chosen, it is necessary to orient it; that is to say, to discover the trace of 001, and that of the edge of the prism. It is to be remembered that the extinction will be positive, according to the rule of Schuster (p. 23, Fig. 19), when it is in the obtuse angle 001 $\wedge$ 010, and negative when it is in the acute angle.

a. The occurrence of the Carlsbad macle, combined with the trace of the easy cleavages, gives the complete solution of the problem; it is enough then to measure the angle (ω) comprised between the two extinctions of the same sign. For the purpose of avoiding all error it will be well to select from the two supplementary angles that which has the same bisectrix as the angle 128° of the basal cleavages (Fig. 27).

For albite $\omega = 168°$. extinction at + 20° in 010.
For oligoclase $\omega = 128°$, extinction at 0° in 010.
For andesine $\omega = 112°$, extinction at —8° in 010.
For labradorite $\omega = 96°$, extinction at —16° in 010.
For anorthite $\omega = 54°$, extinction at —37° in 010.

When one of the profiles 001, 101, 201, can be found, or simply the cleavage of 001 and the coarse cracks parallel to 110 or $\bar{1}10$, the acute angle 001 $\wedge$ 100 can be recognized; the

trace of 100 is in fact in the obtuse angle $001 \wedge \bar{1}01$ or $001 \wedge \bar{2}01$ But, most frequently, it is known *a priorc* where the direction of negative extinction falls. Such is the case when it exceeds 20° and reaches the values characteristic of labradorite or of bytownite; such also when the feldspar is bordered by oligoclase.

(3). The search for sections 010 is often very long. The stage devised by M. de Federov gives a useful means of correcting the position of sections near 010. He has pointed out a process for determining the direction of extinction; it consists in the search for the direction of rotation necessary to bring the nearest optic axis into the field, but it is not applicable to albite, nor to oligoclase No. 2, nor to anorthite.

It is in sections 010 that it is easiest to study the growth-increments of the feldspars, and their changes of composition step by step with their successive consolidations. It is not rare to see labradorites, andesines and even oligoclases thus succeeding each other. But the dominant type is relatively very stable in each stage of the consolidation, and it is very easy, generally, to specify without any uncertainty the nature of the dominant feldspar. Whenever large crystals are susceptible of this examination in the face 010 (and the case is very frequent) it is to be advised.

(4). To what extent do the errors of orientation affect the readings of extinction? The general épures (plates I-VII) can reply to this question with precision. Let us suppose an error of 10° made in the orientation of a section to be studied; in other terms, let us carry forward the pole of the section to the parallel 10° from that of 010. The épures give us, for each position of that pole, the extinction referred to the trace of 010, and the angle of the trace of the cleavage 001 referred to this same trace.

For albite this error of 10° in orientation of the chosen sections gives rise to extinctions varying from 15° to 25°.

The mean error in oligoclase is, in the same manner, ±5°; it descends in andesine to ± 4°, and then rises slightly to labradorite and anorthite.

The mean error of one degree in orientation in the face 010 does not amount to half a degree in the angle of extinction on the cleavage 001. The theoretical reason for such a

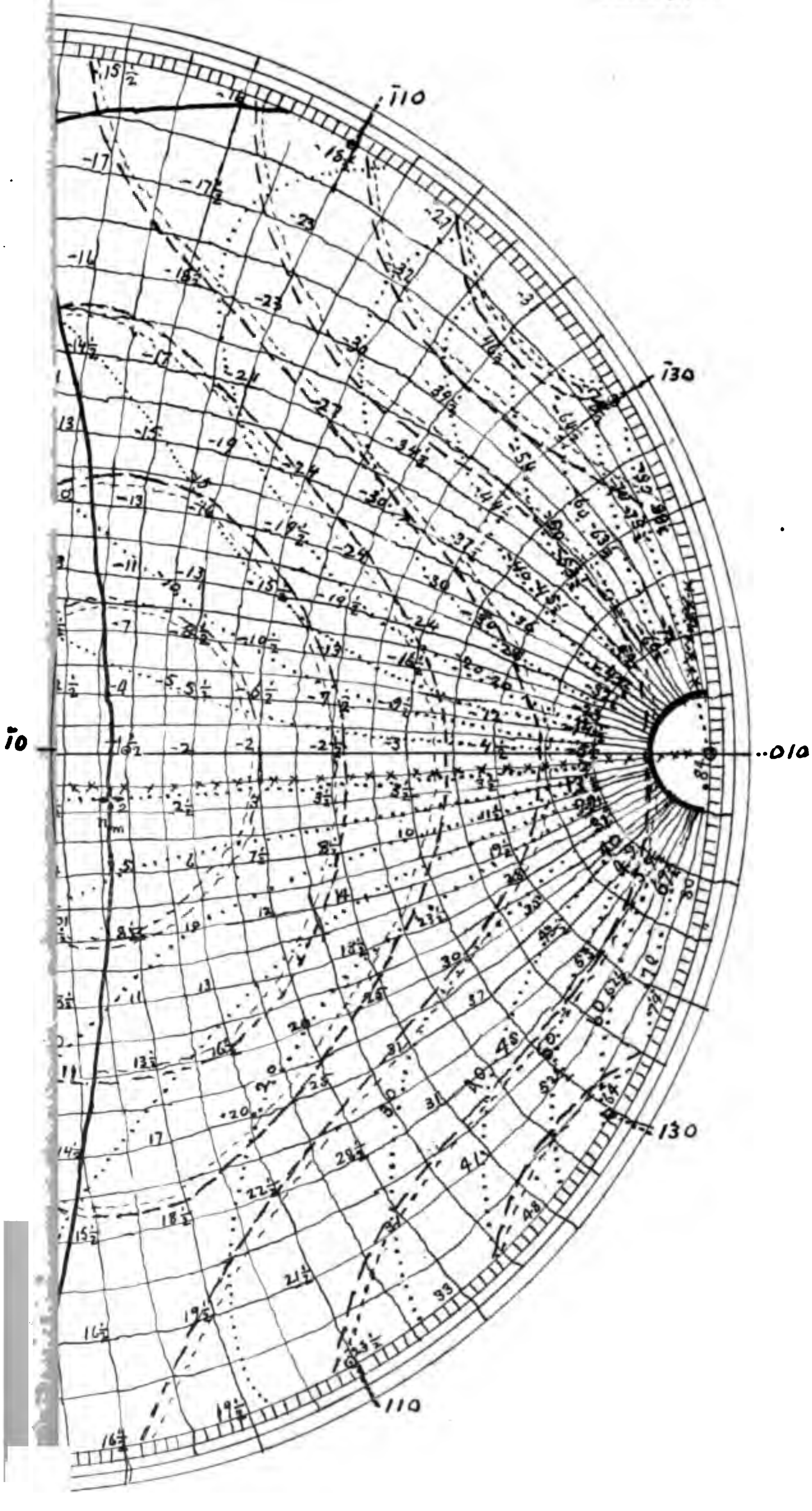

110
130
10
..010
130
110

PLATE [II] III.

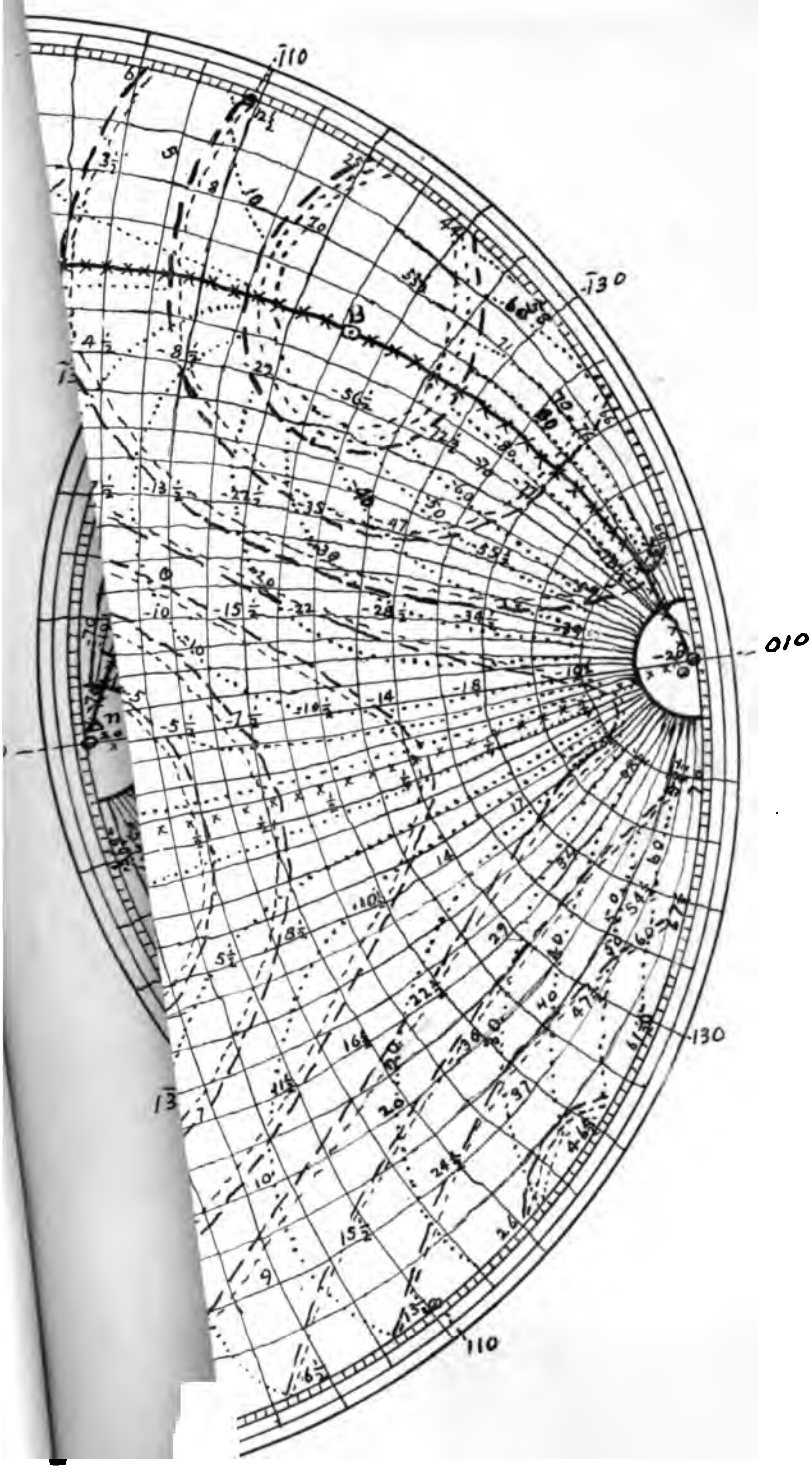
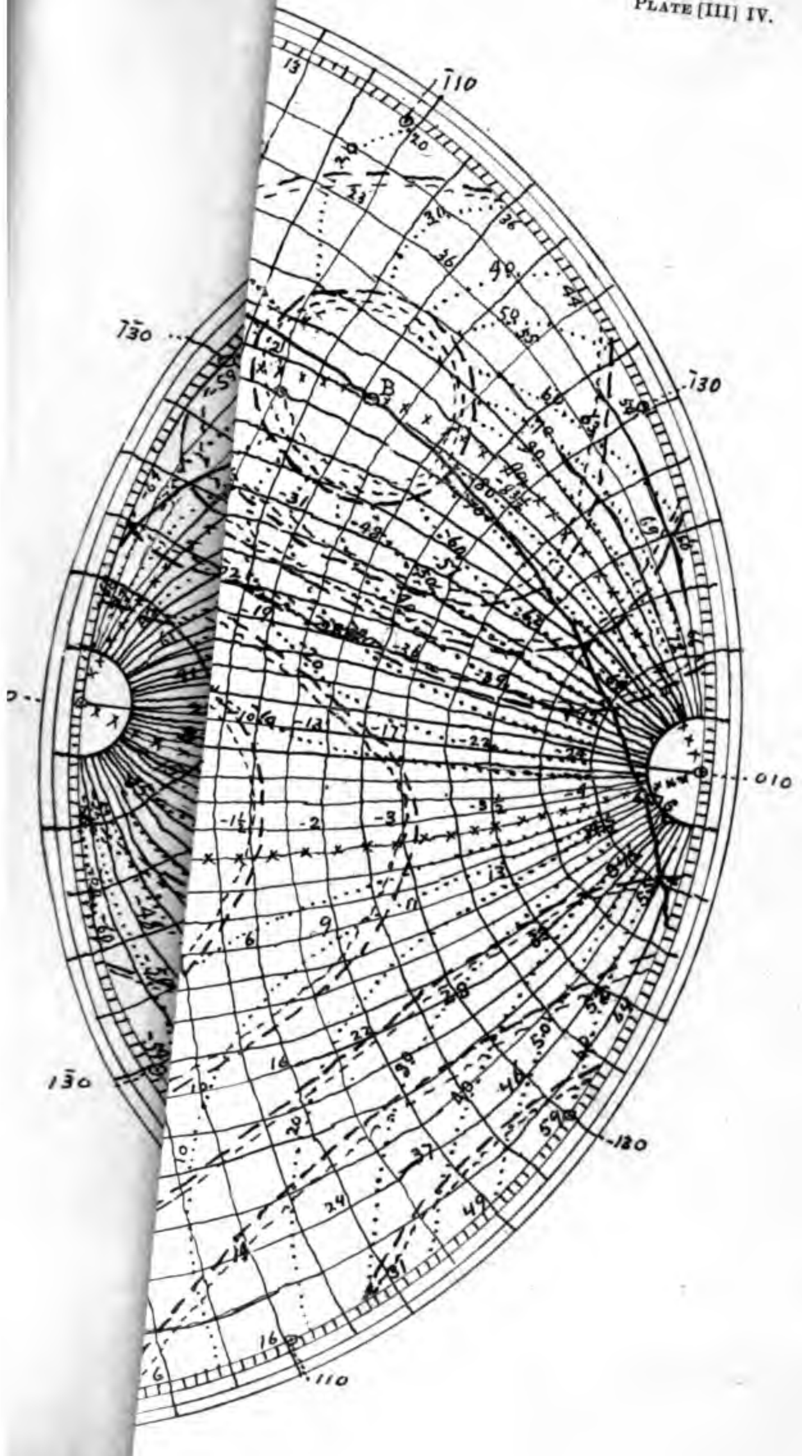


PLATE [III] IV.



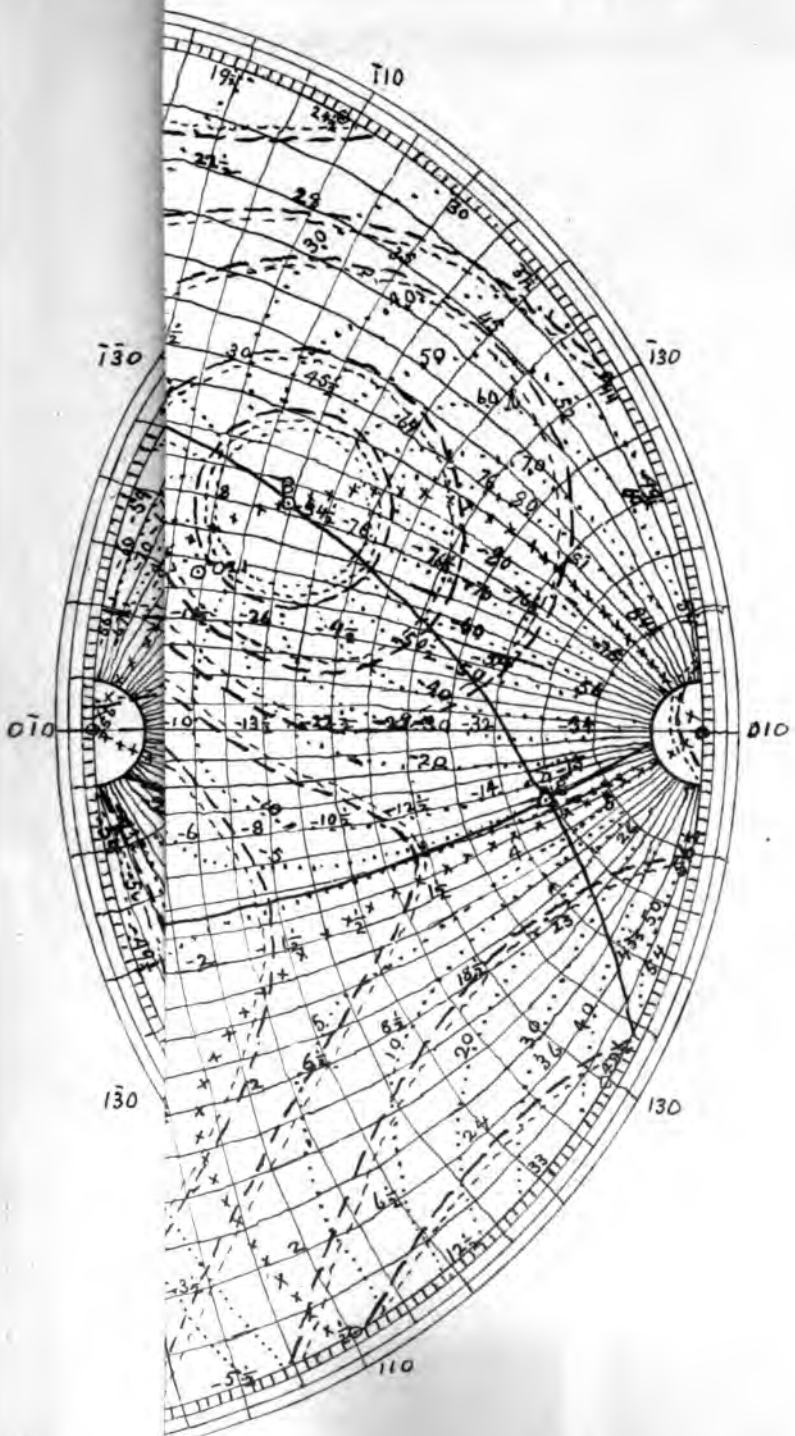

$\bar{1}10$
$\bar{1}30$
$\bar{1}30$
$0\bar{1}0$
010
$1\bar{3}0$
130
110

PLATE [V] VI.

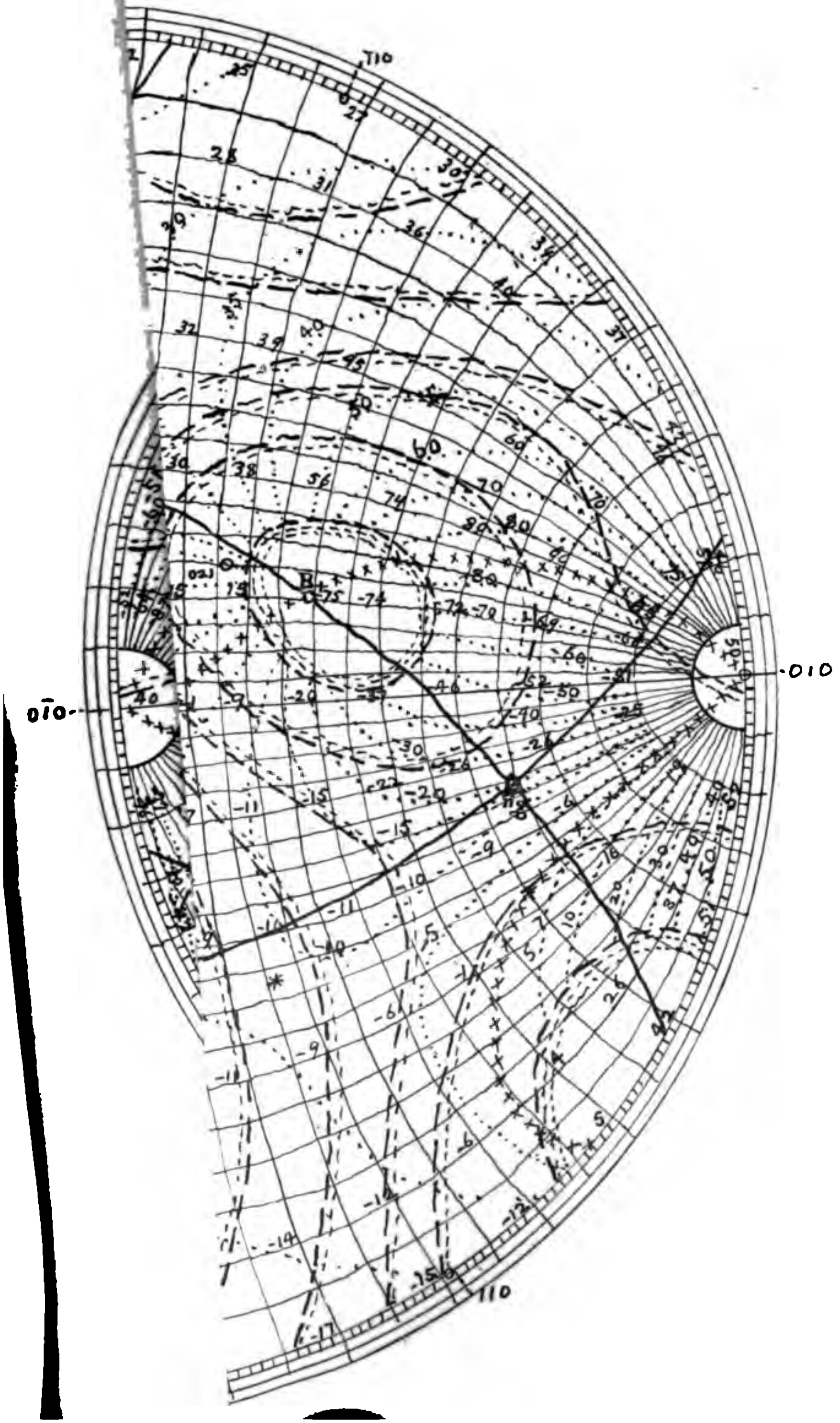
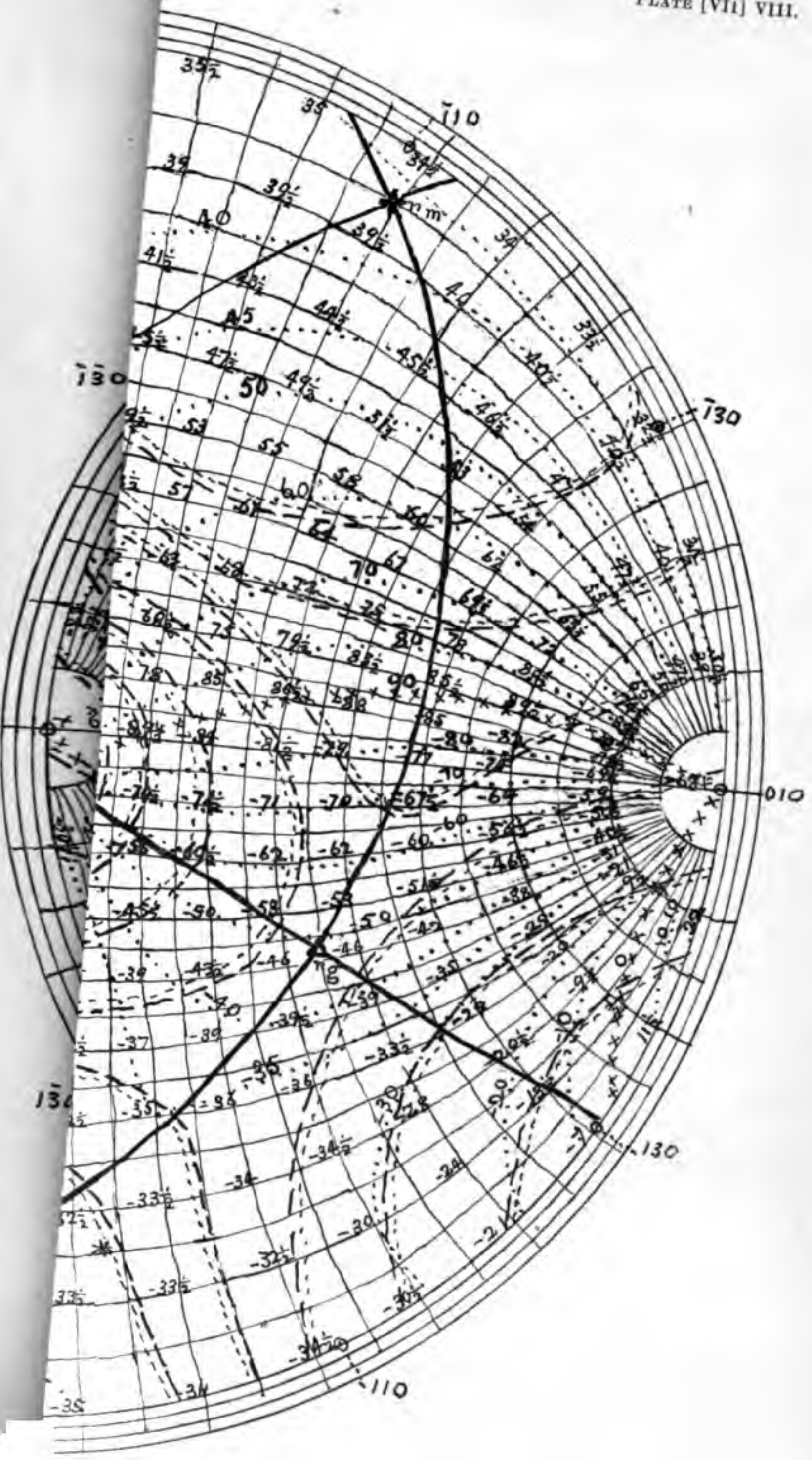


PLATE [VII] VIII.



result is because, in most of the plagioclases, the zones parallel to lines contained in 010 reach their maximum angle of extinction in the neighborhood of that section which serves approximately as the principal plane of elasticity, excepting in anorthite. In the same manner, for the trace of 001, referred to the trace 010, in the same zones, the angles pass a maximum in the neighborhood of 010. Their sum, or their difference, ought, therefore, to vary but little, and 010 is hence well chosen from all points of view.

THE PITTSBURG COAL BED.*

By I. C. WHITE, Morgantown, W. Va.

Among the rich mineral deposits of the great Appalachian field, the Pittsburg coal bed stands preëminent. Other coal beds may cover a wider area, or extend with greater persistence, but none surpass the Pittsburg seam in economic importance and value. It was well named by Rogers (H. D.) and his able assistants of the First Geological Survey of Pennsylvania, in honor of the city to whose industrial growth and supremacy it has contributed so much. Whether or not the prophetic eye of that able geologist ever comprehended fully the part which this coal bed was to play in the future history of the city which gave it a name we do not know; but certain it is that the seven feet of fossil fuel which in Rogers' time circled in a long black band around the hills, and overlooking the site of Pittsburg from an elevation of 400 feet above the waters of the Allegheny and Monongahela, extended up the latter stream in an unbroken sheet for a distance of 200 miles, has been the most potent factor in that wonderful modern growth which has made the Pittsburg district the manufacturing centre of America, and which bids fair to continue until it shall surpass every other district in the world, even if it does not now hold such primacy.

That this claim for Pittsburg's supremacy is valid can hardly be doubted when we see its iron, steel, glass and other products going to every part of the western continent and

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*Vice-president's address before Section E (Geology and Geography), Am. Assoc. Adv. Sci. 1897.

even invading the long established dynasties of the old world. A brief account of the main characteristics of such an important member of the Carboniferous series can hardly fail to be of some interest to geologists and others who desire to learn more of this celebrated coal bed and hence it has been chosen as my theme.

Age. The stratigraphical position of the Pittsburg coal bed is at the base of the Monongahela River series of Rogers. The thickness of this series varies from 250 to 400 feet in different portions of the Appalachian field. It also includes four other coal beds interstratified with sandstones, limestones and shales, but none of these coals have much economic importance since all are thin and impure except over quite limited areas, so that the Pittsburg bed may be regarded as the last of the great coal-making epochs of Carboniferous time.

The lower and middle Carboniferous had passed; the animals and most of the plants that characterize them had vanished; the great Lepidodendra, Sigillariæ, and Calamites of the former floras had been succeeded by dwarfed and puny species of their tribe, while the tree ferns alone of all the larger plants appear to have flourished and attained considerable size. The evening of the Carboniferous day was well advanced, since marine conditions in the Appalachian field had terminated and brackish or fresh water conditions had arisen which continued to the close of the Permian. At the end of this latter epoch 1,500 feet of sediments had accumulated above the Pittsburg coal + the thickness eroded since the close of the Palæozoic, which latter most probably represents a much greater thickness of rocks than the 1,500 feet remaining.

Prof. Fontaine and myself have shown (Report PP. 2nd Geological Survey of Pennsylvania) that beginning with the horizon of the Waynesburg coal at say about 350 feet above the Pittsburg bed, the rocks contain a well defined Permian flora, of types common alike to the Permian of Europe and to the well recognized Permian beds of Texas (Bulletin G. S. A. Vol. 3, pp. 217-218, 1892). Just where in the series this flora was introduced we do not yet know because no systematic collections of fossil plants have been made between the

Waynesburg and Pittsburg coals, and in fact none until we pass below the Pittsburg seam several hundred feet, and reach marine conditions. The coal making epoch of the Appalachian Carboniferous really culminated and its decline began with the deposition of the Upper Freeport bed at the summit of the Allegheny River series of Rogers (No. XIII), since the few fossil plants found in the 600 feet of the Barren or Elk River strata which supervene between the Upper Freeport and Pittsburg coals are either identical with or closely affiliated to Coal Measure types of plants that survive into the Permian flora of Europe and Texas. This is also mainly true of the last marine faunal types occuring at the horizon of the Crinoidal limestone, about 300 feet below the Pittsburg bed, and therefore in Bulletin 65, U. S. G. Survey, page 19, the dividing line between the Upper and Middle Carboniferous was drawn through the midst of the Barren Measures (No. XIV), at the close of the Crinoidal limestone stage when marine life became practically extinct in the Appalachian sediments. Hence the 600 to 700 feet of strata extending from the Crinoidal limestone to the Waynesburg coal, and enclosing the great Pittsburg bed near the centre, may be considered as of Permo-Carboniferous age, or so far as there is any evidence to the contrary, they could just as well be classed as Permian.

The flora of this portion of the column has been studied to only a limited extent, but so far as known, it consists as already stated mainly of those Coal Measure types which pass on up into the undoubted Permian, while the fauna comprises only fresh or brackish water forms, concerning which little or nothing is known, as the fossils (mostly minute) have never been studied. The rocks themselves consist of a monotonous succession of red shales, gray sandstones, and limestones, often highly magnesian but only slightly gypsiferous, and presenting much the same lithological appearance from the Crinoidal limestone to the top of the Permian, 1,500 feet above the Pittsburg coal.

The *Neuropteris morii* Lx., and the large reptilian tracks found by Lyell near Greensburg, Pennsylvania, point to the same conclusion with reference to the age of the Pittsburg bed, namely that it belongs to the closing stage of the Carboniferous period, rather than to the middle of the same.

Area. Before the drill of the petroleum-seeker had penetrated every region of the great Appalachian basin, it was supposed that the Pittsburg coal spread in a continuous sheet under every portion of that area where its outcrop was buried from view. This conclusion was based upon the unfailing continuity of the bed southward for 200 miles from Pittsburg to the head waters of the Monongahela, and also westward into Ohio, and its reappearance on the river of that name at Pomeroy, as also on the Great Kanawha at Raymond City, Pocatallico, and Charleston. But the studies of professor Orton and others in Ohio and my own in West Virginia, aided by the petroleum drilling there, have shown that the coal is absent, or but poorly developed over large areas where it had formerly been considered present. Hence to the list of counties of West Virginia named in Bulletin 65, United States Geological Survey, page 64, where this coal is absent, or in poor development, must now be added Doddridge, Tyler, and probably half of Wetzel, since two tests with the diamond drill near the centre of the latter county found only two feet of coal at a depth of 425 feet below the valley of Fishing creek. This area, together with that previously known to be barren, or to have only a patchy development in West Virginia and Ohio, will aggregate between 4,000 and 5,000 square miles, a rather startling figure when subtracted from the supposed area of a coal-bed so valuable as the Pittsburg in its developed regions.

There has been much speculation as to the area which this coal may once have covered. The isolated patches of the bed in the Georges creek and North Potomac region; the few knobs of it in Preston, Barbour and Upshur counties of West Virginia, together with its presence in the solitary peak of Round Top in Bedford county, Pennsylvania, 45 miles from any other outcrop of the bed, and far east of the Allegheny mountains, have led many geologists to believe that the Appallachian Coal Measures may once have extended northwestward to the Lake region, and eastward possibly to the North mountains, or even to the Blue ridge, having been removed from all this wide expanse by the enormous erosion to which it has been subjected since Carboniferous time. Whether the limits thus assigned were ever

attained by the spread of Coal Measures, we shall probably never know to a certainty, but that there is no inherent improbability in the hypothesis, will appear from the fact that the oldest member of the Carboniferous period, the very hard and erosion-resisting sandstones of the Pocono, with its included coal-beds, extends to the North Mountain region at several points along that great ridge. Of course if the Coal Measures ever covered an area as wide as this lowest member of the Carboniferous, the probabilities are that the area of the Pittsburg bed which has escaped erosion is only a fragment of its former extent. But however this may be, its entire area of workable coal remaining in the states of Pennsylvania, Ohio, West Virginia, and Maryland, does not probably exceed 6,000 or 7,000 square miles.

Structure. Dr. J. J. Stevenson, of the University of New York, was the first geologist to make a detailed study of the Pittsburg coal bed, and to describe the peculiar structure which so distinctly characterizes it, that the coal seam may be thereby identified with great certainty over a wide area. In Report K, Second Geological Survey of Pennsylvania, he shows that a series of thin parting slates and clays subdivide the bed into several definite members, which may be grouped as follows:

"Roof" coals.
"Over"-clay.
"Breast" coal.
    Parting.
"Bearing-in" coal.
    Parting.
"Brick" coal.
    Parting.
"Bottom" coal.

"The "roof" coals are a number of thin layers of coal (two to twelve inches each) separated by shales or clays of varying thickness. Some of the layers are good coal, while others contain much dirt and other impurities. Their number ranges from one to eight, or even more, and their combined thickness seldom exceeds three and one-half to four feet, while the separating slates and clays may be only half as

much, or they may often exceed the coal in thickness by two or three times. In practical mining operations all of this "roof" coal is wasted, because the coal layers make a good support for the overlying strata, and are, therefore, left as the roof of the mine. In this way about 2,000 tons per acre of the Pittsburg coal is always lost without any attempt to recover it. This waste is so large that some of the mining companies are considering the question of putting in crushing and washing machinery with a view to taking down these roof coals, and thus preventing the great loss of fuel which their abandonment entails upon any mine. There is no doubt that the time will come, many generations hence, when at great cost, the Pittsburg bed will be re-mined to secure the coal which is now rejected, both in its roof and bottom members, since all of it would be valuable fuel if freed from the included slates and clays.

The "over-clay" is an impure fire clay, and varies much in thickness, sometimes almost disappearing, and again thickening up to two or even five feet. The clay is usually mottled and much slickensided, so that it becomes a dangerous trap when left as a mine support, since large pieces of it will drop from the roof without any warning sound. Hence it is generally taken down at once, and the miner, has, therefore, given it the name of "draw-slate" in many regions. It often contains what appear to be stems and rootlets of plants.

The next succeeding (downward) division of this seam, the "breast coal" of the miners, also often termed the "main bench," is the most important and valuable division of the whole bed. Its thickness gradually increases from the Pittsburg region (where it is usually about three feet) up the Monongahela, attaining a maximum of six feet at Brownsville, while to the eastward in the Georges creek and North Potomac basin of Maryland and West Virginia, it increases still more to seven and one-half or even ten feet. The top of this member is nearly always of a bony nature for a thickness of one to four inches, and frequently this must be separated and rejected in mining, but even where this is not required, the top of the "breast" coal is distinctly harder than the rest of it, and inclined to a cannelly structure. Westward

to the Ohio river this "breast" division thins and in the Glendale and Moundsville shafts is only 21 inches, according to Mr. J. W. Paul, state mining inspector for West Virginia. It is still perfectly distinct, however, with the twin slates one-fourth of an inch thick each, and enclosing six inches of "bearing in" coal immediately below.

The "bearing-in" coal is so named by the Monongahela river miner, because in mining operations the under-cutting of the "breast" coal is made in this layer, the latter being then wedged or blown down, and the "brick" division subsequently taken up. The "bearing-in" coal is usually brilliant and pure, varying in thickness from three to six inches, and enclosed by two thin parting slates, so much alike in color and structure as to be almost indistinguishable. Their color is usually a dark, mottled gray, and they vary in thickness from one-fourth to one inch. The persistency of these twin slates over all the regions drained by the Monongahela and east to the Georges Creek and North Potomac field, while westward to Wheeling, Bellaire and the neighboring regions of Ohio they still appear to be present, is one of the remarkable features of this coal-bed. When, however, the areas of this coal south of the little Kanawha river in West Virginia, and west from the Muskingum in Ohio, are examined, these twin slates are not found, or if represented are no longer recognizable as the Monongahela partings, but the "roof" coals and "over-clay" appear to be present.

The "brick" coal comes next under the lower of the twin slates, and was so named by the Monongahela river miners because it comes out in oblong, rectangular blocks resembling the shape of common bricks. It is usually about one foot thick. The parting which separates the "brick" coal from the next lower member is always present along the Monongahela from Brownsville to Pittsburg, and it is also represented in the Georges Creek and North Potomac field, but in the Fairmont region it is only occasionally present, the bed there being generally undivided below the "bearing-in" coal.

The "bottom" member is from twelve to twenty inches thick along the Monongahela, and contains so many thin, slaty, sulphurous laminæ, that it is usually not taken out in

mining, and thus another thousand tons per acre of this bed is wasted, though in the Fairmont and Cumberland (Georges Creek) regions it is mined and sold with the rest of the coal. The twelve to fifteen inches of good fuel in this member could always be recovered by crushing and washing.

The structure here described can be best illustrated by giving an actual section of the coal at its type locality. In the Ormsby mine at Twenty-first street, Pittsburg, where mining operations have been carried on for more than 60 years, Mr. J. Sutton Wall took the following measurements (K 4, Second Geological Survey, Pennsylvania, page 177):

		Inches.	
"Roof"..	Coal	6	56"
	Clay	2	
	Clay	8½	
	Parting	0½	
	Coal	2	
	Clay	9	
	Coal	8	
	Parting	0½	
	Coal	9	
	Clay	0½	
	Coal	5	
	Parting	0½	
	Coal	2	
	Parting	0½	
	Coal	2	
"Over"-clay			9"
"Breast" coal		33"	61¾"
	Parting	0¼	
"Bearing-in" coal		4	
	Parting	0¼	
"Brick" coal		10	
	Parting	0¼	
"Bottom" coal		14	
	Total thickness		10'6¾"

Substantially this structure may be seen at every mine between Pittsburg and Brownsville, and on beyond for many miles (see Reports K and K 4, Second Geological Survey, Pa).

East of the Monongahela, on the Youghiougheny river, the same structure is well illustrated by two sections which Mr. W. S. Gresley, F. G. S. A., measured for me with great care at the W. L. Scott estate mines, of which Mr. Gresley is superintendent at Scott Haven, Pennsylvania. The first one of these is near Scott Haven, and reads as follows:

		Inches.	
"Roof"..	Coal, several films of dirt	3¼	48¼"
	Shale, black, earthy	2	
	Coal	2¾	
	Shale, gray, streaks of coal near top	11	
	Bone (hard, dull, impure, coaly, layer)	1	
	Coal	2½	
	Shale, black	0¼	
	Coal	1¾	
	Shale, black, coaly	1	
	Coal	3	
	Slate, gray, with irregular coal streaks	4½	
	Coal, compact, free from "binders"	9¼	
	Slate, with coal streaks	1½	
	Coal	2½	
"Over"-clay (impure, fireclay, light gray above, getting browner and then a much darker gray with coal streaks of irregular shapes, especially towards base)		10½"	
"Breast" coal (with 1½ inches of bone at top, and next 10" harder than the rest of bench)		41½"	72⅜"
	Shale, dark grayish brown, mottled	0¾	
"Bearing-in" coal, clear and brilliant		4	
	Shale, dark grayish brown, mottled	0½	
"Brick" coal clear and brilliant		11	
	Shale, parting	0⅛	
"Bottom" coal	Coal with a few thin dirt layers	12½	
	Shale	0¼	
	Coal, bright, clean	2	
Total thickness of bed		10' 5⅛"	

The other section made by Mr. Gresley is from the "Pacific Mine," near Scott Haven, and three miles distant from the section just given. It is as follows:

		Inches.	
"Roof"..	Coal	1¼	50"
	Shale, light	2¼	
	Coal, with a few dirt partings	5	
	Shale	0½	
	Coal	2	
	Fireclay, light, bastard	14½	
	Coal, with a few dirt partings	9	
	Shale	1½	
	Coal with thin dirt lenses	12	
	Shale	0¼	
	Coal	1¾	
"Over"-clay	Fireclay, light, inferior, much darker toward base with meandering streaks and veins of brilliant coal.	10½"	
"Breast" coal,—Upper 10 inches harder than the rest		42"	70⅝"
	Shale, mottled	0¼	
"Bearing-in" coal		3¾	
	Shale, mottled	0½	
"Brick" coal		11	
	Shale, parting	0⅛	
"Bottom" coal		14	
Total thickness of bed		10' 11⅛"	

A third section measured by Mr. Gresley, three miles distant from either of these differs so little from them that it is useless to give it.

How perfectly this great coal-bed preserves the Pittsburg type of structure, is shown from the following section sent me by Mr. R. L. Somerville, superintendent of the Georges Creek Coal and Iron Company, Lonaconing, Maryland. The locality is east of the Allegheny mountains, and 150 miles from Pittsburg. It is as follows:

	Inches.
"Roof" coal with slate parting below	20
"Breast" coal 6" of bone on top	91
"Slate"	1
"Bearing in" coal	4½
Slate	0¾
"Brick" coal	16
Slate	0¼
"Bottom" coal	15
Total thickness of bed	12', 4½"

This type of structure is practically universal over all of the Pennsylvania, Maryland and eastern Ohio area of the bed. The different members vary considerably in thickness, as for instance the gradual increase of the "breast" coal from three feet at Pittsburg to six at Brownsville, 58 miles up the Monongahela river, or to seven and even ten feet in the Georges creek and North Potomac regions of Maryland and West Virginia, or a decrease may take place in the same to thirty and sometimes to twenty inches, as in the Wheeling and Bellaire regions, but each of the main sub-divisions can be distinctly recognized, so that whether at Fairfax Knob, on the summit of the Allegheny mountains, 3,200 feet above the sea, or deep down in the centre of the great Appalachian trough buried under 1,500 feet of sediments, the explorer can readily identify this great coal-bed, not only from its associated rocks, but from its stratagraphical elements as well, and often from even the fracture of the coal. I once had a practical illustration of this latter peculiarity of the Pittsburg seam. About the year 1880 a coal bed was discovered near the summits of the hills, south from Huntington, West Virginia, and on one of my excursions to

the southern portion of the state, with the University students of geology, the mayor of Huntington requested me to determine, if possible, to what horizon the coal belonged. It proved an easy problem to identify it since the Crinoidal limestone, with its characteristic fossils, was easily found in the bed of Four Pole creek, fifty feet above the Ohio, and above it the ordinary rock succession of the Barren or Elk river series. But, being anxious to know what the miner who was digging the coal thought of the matter, he was interrogated, and replied as follows: "I don't know anything about geology, but I dug coal several years in the Pittsburg seam, along the Monongahela, and this coal reminds me of the Pittsburg in the way it breaks into blocks." Thus had the miner correctly diagnosed the horizon of the bed by his own peculiar methods, though 300 miles distant from where he had learned its structure, with only the tools of his trade and his bright observing mind as his guidance, strong testimony certainly to the persistence of even the internal structure of the bed.

The oil-well driller is required to identify this coal correctly in the great petroleum districts of West Virginia and Pennsylvania, between the Ohio and the Monongahela rivers, where it is buried from sight by the Permian beds all the way from 500 to 1,500 feet. It is there a key-rock for determining the amount of casing and the depth of the oil sands, and thus many dollars of expense depend upon the correctness of the driller's identification. This he does by observing the character of the drillings as brought to the surface by the sand pump, or in other words he observes the stratigraphic succession in his own peculiar way, and in the hundreds and even thousand of holes drilled in this area, he has only two or three mistakes charged against his accuracy of discrimination.

A word of friendly criticism and kindly warning concerning the methods of the United States Geological Survey, especially in its Coal Measures work, but equally applicable to the other formations, becomes in this connection an imperative duty.

In recent years a theory seems to have been adopted by the United States geologists who have been studying the

Coal Measures, that no coal bed can be certainly identified beyond the area of its continuous outcrop, and hence must be given a local name for every isolated area, thus adding greatly to the burden of geological nomenclature, a fault of geologists everywhere, which has become so grievous that the International Congress has been invoked this summer to consider a remedy for the matter. The confusion produced by this useless giving of many names to the same thing is an evil for which a remedy must be speedily found, or it will soon bring all geological work into deserved contempt in the minds of laymen.

The United States geological survey which is doing such splendid work along many lines ought to be a model in the matter referred to, but is now the chief offender. Let us hope and urge that a reform in the methods of work which lead to such undesirable results shall soon be inaugurated.

The old and well established names of the New York, Pennsylvania and Virginia surveys, rendered classic by the labors of such men as Hall, Emmons, the Rogers brothers, Lesley, and many other faithful geologists, should not be lightly cast aside, and the work of these noble pioneers ignored, unless positive error can be proven.

It is no argument in favor of the methods complained of, to say that the geologist is not reasonably certain of identity of horizon, for that is the fault of the observer and his methods in not wisely attacking the problems of stratigraphy. It will hardly do to admit that the untutored miner and unlettered petroleum driller are better geologists than men trained as experts in geology. What we need more than anything else is a closer and more minute study of the individual beds, such as Mr. Gresley, for instance, has been making on the Pittsburg coal, and if this method of work were pursued the geologist would find but slight need of the introduction of new names for old and well-named things. It was with the hope of emphasizing the necessity and importance of observing the smaller details of stratigraphy more closely, that I have dwelt at length upon the characteristic structure of a single coal bed.

REVIEW OF RECENT GEOLOGICAL LITERATURE.

Seventeenth Annual Report of the United States Geological Survey to the Secretary of the Interior, 1895-96. CHARLES D. WALCOTT, Director. In Three Parts. Washington, 1896. Part I. Director's Report and Other Papers. Pages xxii, 1076; with 67 plates, and 43 figures in the text.—Part II. Economic Geology and Hydrography. Pages xxv, 864; with 113 plates, and 74 figures in the text.—Part III. Mineral Resources of the United States, 1895: (first volume) Metallic Products and Coal, pages xxi, 542; (second volume) Nonmetallic Products, except Coal, pages 543-1058; with 13 plates and 3 figures in the text.

The report of the Director, in 200 pages, gives brief summaries of the work done by the several divisions of the survey, a detailed statement of the expenditures during the fiscal year, and a short biographical sketch of the late Prof. George H. Williams. In geological exploration and mapping, four parties worked in the New England region; seven in the Appalachian region; four in the Atlantic Coastal Plain region; four in the Interior or Mississippi region; six in the Rocky Mountain region; and seven in the Pacific region. Six parties conducting field observations in paleontology are reported. In topographical mapping, work was prosecuted in twenty-four States and Territories. The entire area surveyed during the year was 48,066 square miles, of which about 44,000 square miles are designed for publication on the scale of 1:125,000, or about two miles to an inch, while the remainder is nearly all to be on the scale of 1:62,500. The total appropriations for the survey during the fiscal year ending June 30, 1896, were $675,530.75; and the total expenditures $647,075.60.

Seven other papers are published in Part I, as follows: Magnetic Declination in the United States, by Henry Gannett, pages 203-440, with two plates and three figures; A geological Reconnaissance in Northwestern Oregon, by Joseph Silas Diller, pages 441-520, with plates 4-16, and figures 4-17; Further Contributions to the Geology of the Sierra Nevada, by Henry W. Turner, pages 521-762, with plates 17-47, and figures 18-22; Report on Coal and Lignite of Alaska, by William Healey Dall, pages 763-875, with plates 48-58, and figures 23-25, and three appendices (I. Report on the Fossil Plants Collected in Alaska in 1895, as well as an Enumeration of those previously known from the same region, with a Table showing the Relative Distribution, by F. H. Knowlton, pages 876-897; II. Report on Palæozoic Fossils from Alaska, by Charles Schuchert, pages 898-906; III. Report on the Mesozoic Fossils, by Prof. Alpheus Hyatt, pages 907, 908); The Uintaite (Gilsonite) Deposits of Utah, by George Homans Eldridge, pages 909-949, with plates 59, 60, and figures 26-33; The Glacial Brick Clays of Rhode Island and Southeastern Massachusetts, by N. S. Shaler, J. B. Woodworth and C. F. Marbut, pages 951-1004, with plates 61, 62, and figures 34-43 (reviewed in the last Am. Geologist, p. 328); and

The Faunal Relations of the Eocene and Upper Cretaceous of the Pacific Coast, by Timothy W. Stanton, pages 1005-1060, with plates 63-67.

Mr. Gannett's paper, compiling and discussing the magnetic declination in all parts of the United States, is designed to meet the needs of land surveyors who use the magnetic needle, or who have occasion to deal with old surveys run by the needle. The resulting map shows lines of equal declination for the year 1900, the extremes being about 22 degrees west on the northeastern boundary of Maine, and 23 degrees east at Juan de Fuca strait.

The part of northwestern Oregon described by Mr. Diller extends from the Columbia about 200 miles south to the Umpqua and Coquille rivers, with a width of about 75 miles back from the coast. It is found that the chief mass of the Coast range, from near the Columbia to the Coquille, consists of Eocene rocks, which are shales and sandstones, with basalt and associated tuffaceous materials. Oligocene, Miocene, and scanty Pliocene beds occupy the lower country. Above these are marine Pleistocene beds, formed during a depression of 200 feet or more; but this was succeeded by an elevation of the land considerably above its present hight, as shown by the submarine continuation of the Columbia river valley. The chief mineral resources are deposits of coal, of which about 75,000 tons were mined in 1895; limonite, scantily mined in several places; and gold, with platinum, iridium, and osmium, which occur most notably in black sands along the sea beach and to a short distance at and north of the mouth of the Coquille river.

Mr. Turner supplements his previous memoir on the Sierra Nevada, published in the Fourteenth Annual Report of this survey, of which a preliminary abstract appeared in the Am. Geologist (Vol. XIII) for April and May, 1894. His later articles in this magazine for June, 1895, and June, 1896, present portions of the subjects which are more fully treated here. The Sierra Nevada is regarded as "a block of the earth's crust that has been quite rigid since middle Cretaceous time, although it has since, in common with most of California, experienced a considerable elevation." This paper contains much detailed description of the rocks of the mountain belt, both sedimentary and igneous, with many plates of their thin sections.

The lignitic coal deposits of Alaska, described by Dr. Dall, occur in the Kenai formation, which has an extensive geographic distribution. They will probably be profitably mined for domestic use and for exportation to California, competing with the lignite of British Columbia. The Kenai group, consisting of conglomerate, sandy slates, and shales, with a rich fossil flora, wood, and lignite, is regarded as probably Oligocene and as of the same age with the Atane leaf beds of Greenland and the plant beds of Spitzbergen, although Heer classed them all as Miocene. The discussion of this question is accompanied by good description of the other Tertiary formations of Alaska. The ensuing Glacial and Post[illegible]e been supposed (rightly, according to the review[illegible]ented by the Ground ice forma-

tion, exposed on the shore of Eschscholtz bay and in other localities, and the overlying Kowak clays, which contain many mammoth bones and tusks; but Dr. Dall inclines to assign them (and also the beds up to 5,000 feet in the basal part of Mt. St. Elias, containing numerous species of marine shells, all now living, as described by Russell) to Pliocene rather than Pleistocene time. The concluding portion of the paper and its appendices treat very fully of Alaskan paleontology.

Immense supplies of a variety of asphalt, named uintaite by Prof. W. P. Blake in 1885, but more recently known commercially as gilsonite, occur in the west half of the Uinta basin of Utah. The uintaite, as described by Mr. Eldridge, fills straight vertical cracks in Eocene strata, its veins being from a sixteenth of an inch to eighteen feet across, and from a few hundred yards to eight or ten miles long. The cracks are thought to have originated when the gentle synclinal fold of this basin was formed, and to have been immediately filled by injection of the asphalt in a plastic or melted condition: but the author cannot suggest the condition in which it existed prior to its flow into the cracks. Uintaite is chiefly used in the manufacture of varnishes, for which it is delivered in St. Louis and Chicago at $40 to $50 per ton.

Mr. Stanton, from his study of the Chico and Téjon faunas, refers the former to the Cretaceous and the latter to the Eocene. The supposed Tertiary types in the Chico fauna are shown to be few and limited to persistent species which have changed little from the Cretaceous to the present day. In California these formations are conformable, wherever sections have been discovered; and it is suggested that the later fauna was not here developed from the earlier, but succeeded to its place by migration.

Part II comprises eight important papers, as follows: The Gold-quartz Veins of Nevada City and Grass Valley, California, by Waldemar Lindgren, pages 1-262, with 24 plates, and 37 figures in the text; Geology of Silver Cliff and the Rosita Hills, Colorado, by Whitman Cross, pages 263-403, with plates 25-36; The Mines of Custer County, Colorado, by Samuel Franklin Emmons, pages 405-472, with plate 37, and figures 38-43; Geologic Section along the New and Kanawha Rivers in West Virginia, by Marius R. Campbell and Walter C. Mendenhall, pages 473-511, with plates 38-49; The Tennessee Phosphates, by Charles Willard Hayes, pages 513-550, with plates 50-55, and figure 44; The Underground Water of the Arkansas Valley in Eastern Colorado, by Grove Karl Gilbert, pages 551-601, with plates 56-68, and figures 45-49 (reviewed in the Am. Geologist, Jan., 1897, Vol. XIX, pp. 57-60); Preliminary Report on Artesian Waters of a Portion of the Dakotas, by Nelson Horatio Darton, pages 603-694, with plates 69-107, and figures 50-65 (reviewed in the last April Am. Geologist, pp. 274-6); and The Water Resources of Illinois, by Frank Leverett, pages 695-828, with plates 108-113, and figures 66-70 (reviewed in the last June Am. Geologist, p. 418), to which a final chapter, An Account of the Palæozoic Rocks Explored by Deep Borings at Rock Island, Ill., and its Vicinity, is contributed by J. A. Udden, pages 829-849, with figures 71-74.

In these economic and hydrographic papers, and in the two volumes forming Part III, on the resources of our mines and quarries in 1895, compiled by many specialists under the supervision of Dr. David T. Day, a vast amount of information is presented, descriptive, historical, and statistical, which is adapted directly to promote the industries and material prosperity of the whole country.

The first paragraph of Dr. Day's report sums it up very concisely, and indicates its close bearing on our business interests, as follows: "The total value of the mineral products of the United States for the year 1895 increased nearly one hundred million dollars beyond the value of 1894, or from $527,144,381 to $622,687,668. This increase is a long step toward recovery from the depression to which the mineral industry, like all others, has been subjected. The total value is slightly less than the greatest we have ever known, which was over $648,000,000, in 1892. In terms of quantities produced, instead of value received, 1895 is greatest. In other words, prices are lower."

Papers on iron ores, by John Birkinbine, and on the iron and steel industries, by James M. Swank, occupy 49 pages; statistics of gold and silver production, 8 pages; and a paper on copper production, mainly statistical, by Charles Kirchhoff, 49 pages; while lead, zinc, quicksilver, manganese, tin, aluminum, nickel and cobalt, chromic iron, antimony, and platinum, are similarly noticed, with tables of their recent yearly production. The paper on coal, by Edward W. Parker, fills 258 pages. Coke (78 pages), petroleum (111 pages), and natural gas (18 pages), are treated by Joseph D. Weeks; asphaltum (8 pages), by Mr. Parker; stone (53 pages), by William C. Day; clay (64 pages), by Jefferson Middleton; cement (13 pages), by Spencer B. Newberry; and precious stones (32 pages), by George F. Kunz; besides other papers, with statistics, on flourspar and cryolite, mica, asbestos, graphite, mineral paints, barytes, abrasive materials, phosphate rock, sulphur and pyrites, gypsum, salt, and mineral waters. W. U.

Iowa Geological Survey, Vol. 6, Annual Report, 1896, with accompanying papers. SAMUEL CALVIN, State Geologist. (555 pp., 11 pls., 11 maps; Des Moines, 1897.)

From the fifth annual report of the state geologist, which is included in this volume, the following facts concerning the work of the Iowa survey are taken: During 1896 six counties were surveyed and during previous years fourteen counties. In twelve other counties the field work is partly or wholly done, making a total of thirty-two counties in which detailed areal investigations have been conducted. At the same time certain features of other counties have been studied in connection with reports on special subjects, as the report on coal deposits or that on artesian wells. In the areal county work those counties have been selected first which contain deposits of great economic importance or which offer a means of solution of a large number of geological problems. During the last year [illegible] attention has been given to the study of the Devonian, the [illegible] Measures and the Pleistocene, and in

the last a marked advance has been made, due largely to the work of Messrs. Calvin and Bain. A summary statement of the results of their study of the drift deposits has already been given in this journal (Vol. XIX, pp. 270-272, April, 1897).

The present volume contains reports on six counties, each report being accompanied by two maps, one showing the pre-Pleistocene and the other the Pleistocene geology, but the latter map is omitted in the report on Madison county. These county reports are as follows: Johnson and Cerro Gordo counties, by Samuel Calvin; Marshall county, by S. W. Beyer; Polk and Guthrie counties, by H. F. Bain; Madison county, by J. L. Tilton and H. F. Bain. The reports on Johnson and Polk counties have already been reviewed in this journal (Vol. XX, p. 273, Oct., 1897; Vol. XX, p. 334, Nov., 1897).

A geological map of the state is presented which shows the outlines of the following divisions: Algonkian, Cambrian, Ordovician, Silurian, Devonian, Mississippian, Des Moines, Missourian and Cretaceous. This map is more accurate than those formerly published, as must necessarily be the case as the detailed work of the survey is extended. The limits of the Cretaceous are more carefully defined and the rocks of this system are found to cover considerably more territory than was supposed a few years ago. The same increase in the known geographical limits of the Cretaceous is also evident in the later reports of the Minnesota survey. U. S. G.

Volcanoes of North America: a reading lesson for Students of Geography and Geology. ISRAEL C. RUSSELL. New York. The Macmillan Company, 1897. Octavo, 346 pages, $4.00.

This review is quite similar in scope and plan to the former works of the same author on the lakes and on the glaciers of North America. It opens with a chapter on the characteristics of volcanoes, occupying 126 pages, in which Stromboli, Vesuvius, Krakatoa, the Hawaiian islands and the lava fields of the Deccan and of Columbia are taken as types, to which is added also a note on the trap-rocks of the Newark system, the last being the most recent of the volcanic epochs of the Atlantic side of North America.

The author is responsible for many of the descriptions here given, having examined several of the most important volcanic regions of North America, but he has compiled from others many other descriptions, some being from the reports of the United States Geological Survey, and from the Geological Survey of Mexico. Great value is added to the work by the fine illustrations with which it is accompanied. The volume is a welcome addition to the geological literature of North America, and serves to supply for America what those of Scrope and of Geikie have given to the geology of Europe.

Without attempting a thorough review, attention may be called to the lack of mention of recently extinct volcanoes in New Mexico, and even in Texas, further east than has been allowed by the author. He specifically excludes some which have been enumerated more recently

by Hill in *Science* (Oct. 15, 1897), first described by Marcou in 1857. Again, there is some question as to the propriety of including the central area of the Black Hills and of other similar mountain ranges in a description of laccolitic phenomena, and least of all in the category of volcanoes. The axis of uplift of the Black Hills dates from Archæan time as old as the protaxis of New England, and has certainly maintained an island in the ocean during all its subsequent geological history. There have been later upliftings, both gradual and catastrophic, but there is no evidence that the Mesozoic and Tertiary beds ever passed intact over the summit of Custer and Harney peaks. It is well known that the Potsdam sandstone of the region is composed of debris of the older rocks, including Potsdam gold placers derived from lodes that must even at that date have been elevated above the level of the ocean. There are no known laccolites or volcanoes in the region of the Black Hills of date earlier than the Mesozoic and probably not earlier than the Tertiary. But Bear Butte, on the eastern side, is probably a remnant of a late intrusion, while Heenya Kaga, on the west side is an extinct volcanic crater later at least than the Carboniferous, and should be added to the list of Hill of extinct craters further east than the Spanish peaks. N. H. W.

Beiträge zur Kenntniss einiger palæozoischer Faunen Sud-Amerikas, von Herrn. E. Kayser in Marburg, Hess. (Reprint, a. d. Zeitschr. d. Deutsch. geolog. Gesellschaft, 1897.)

This work is devoted to a description of the Paleozoic faunas of the strata of the Argentine Confedération, chiefly its middle and northwestern parts, and of lake Titicaca in Bolivia. The region is that of the high table land on the eastern slopes of the Andes, where these mountains change from a direct north to a northwest course.

Dr. Kayser had already described a number of Cambrian and other fossils from this region, and now adds largely to the number and illustrates his paper with six excellent plates in which the new species are figured.

The Cambrian fossils occur in a fine grained micaceous sandstone, having quartz pebbles and seams of slate. The following species are described: *Liostracus steinmanni, Lingulella* cf. *ferruginea* Salt., *L. ulrichi L.* cf. *davisii* Salt., *Agnostus irugensis* [Section Lævigati].

From a careful study of the species Dr. Kayser considers that these fossils indicate the horizon of the Paradoxides beds.

The above author also revises his opinion as to the age of the Argentine Cambrian fauna formerly described by him. On the strength of the occurrence of Orthis lenticularis and of an Olenus he had referred this fauna to the upper Cambrian, but in concurrence with Dr. W. C. Brögger he is now inclined to think that the supposed Olenus should be referred to Crepicephalus (Ptychoparia), and that the Orthis alone will not confirm the reference to Upper Cambrian. This change he is the more inclined to since the fauna described in the present paper, and

that previously made known, come from the same yellow-brown, fine-grained micaceous sandstones.

The Lower Silurian fauna occurs in a sandstone in the province of Salta, in northwest Argentine, but in limestone and dolomite in the middle of that country, in the province of San Juan. The species described are: *Megalaspis* sp., *Bellerophon* sp., *Didymograptus* sp., *Illenus argentinus*, *Maclurea avellanidæ*, *Leptæna sericia* Sow., *Orthis cælligramma* Dalm (?).

The species here figured with others previously described are considered to indicate a considerable range of Lower Silurian beds, including the orthoceratite limestone at the base and other beds toward the top of the system.

The Devonian fauna of middle Argentina is contained in clay slate (lower part of the terrane) and slate and graywacke (upper part).

The following species are described:

Cryphæus, *Phacops* cf. *rana* Green, *Homalonotus* sp., *Orthoceras*, sp., *Naticopsis* ? sp., *Bellerophon* sp.,*Bellerophon* aff. *murchisoni* d' Orb., *Conulara quichua* A. Ulrich, *Tentaculites* sp., *Leptodomus* sp. *Pholadella radiata* Hall, *Allorisma* sp., *Tropidoleptus fascifer* n. sp., *Liorhynchus bodenbenderi* n. sp., *Liorhynchus* ? *brackebuschi*, n. sp. *Meristella* ? sp., *Leptocœlia acutiplicata* Conr., *Vitulina pustulosa* Conr. *Spirifer antarcticus* Morr. and Sharpe, *Orthothetes* sp., *Orthothetes* cf. *arctostriatus* Hall, *Chonetes falklandica* Morr. and Sharpe, *Chonetes fuertensis*, n. sp., *Chonostrophia*, *Lingula* (*Dignonia*) *subalveata* n. sp., *Orbiculoidea* cf. *humilis* Hall.

The fossils are considered to indicate the lower and middle parts of the Devonian system.

In this region the Silurian (Upper) is wanting, as the Devonian beds rest directly upon the Lower Silurian limestone, and consist of strata of the kind above described, having a thickness of several hundred to two thousand metres. Three fossiliferous horizons have been recognized in this mass of sediment.

The Devonian fossils of lake Titicaca were found in loose pieces scattered over the surface of an island-like elevation in the lake and plain. The fossils found were *Leptocœlia flabellites* Con., a Retzia and a Homalonotus.
G. F.

Petrology for Students. An Introduction to the study of rocks under the microscope. By ALFRED HARKER. (2nd edition, revised, viii and 334 pp.; University Press, Cambridge, 1897, price, 7s. 6d.)

The second edition of this text book, revised throughout and in part rewritten, does not differ materially in manner of treatment from the well known first edition, which was noted in the Geologist, vol. xvii, p. 327, and thus does not require an extended review. The divisions of igneous rocks—plutonic, hypabyssal and volcanic—are retained, and the amount of detail as regards reference to special types and descriptions is increased, especially for American localities. The

author has made it a point to devote more attention to American rocks, and references to the work of writers on petrology on this side of the Atlantic are numerous. U. S. G.

Geological Section from Moscow to Siberia and Return. By PERSIFOR FRAZER. (A brochure of 52 pages read before the Academy of Natural Sciences of Philadelphia, Oct. 26th, 1897.)

The paper in question is an admirable summary of the chief points of geologic interest seen by the author on the great excursion to the Ourals previous to the meeting of the International Congress of Geologists at St. Petersburg.

Dr. Frazer, as he states, has drawn freely upon the splendid guide prepared with such great labor and expense by the Russian geologists but he has so interwoven his own observations with the luminous details, given in the guide as to make a very interesting story concerning the geology of the region traversed. A born diplomat, Dr. Frazer has treated with much skill, and in the happiest manner, the extremely delicate question of the disputed points in the Oural mountain region. His ready and accurate knowledge of French has enabled him to perform a valuable service for his less fortunate brother geologists, by epitomizing in good English the main features of interest comprised in the Russian (French) guidebook. His tribute of praise for the Tzar, the Russian geologists, and all the Russian people, is not less happy than just.

I. C. W.

MONTHLY AUTHORS' CATALOGUE OF AMERICAN GEOLOGICAL LITERATURE, ARRANGED ALPHABETICALLY.*

Bannister, H. M.

The drift and geologic time. (Jour. of Geol., vol. 5, pp. 730-743, Oct.-Nov. 1897.)

Berkey, C. P.

Geology of the St. Croix dalles. Pt. I. (Am. Geol., vol. 20, pp. 345-383, pls. 20-22, Dec. 1897.)

Burwash, E. M.

Geology of the Nipissing-Algoma line. (Ontario Bureau of Mines, 6th [1896] Rept., pp. 167-184, 1897.)

Chamberlin, T. C.

A group of hypotheses bearing on climatic changes. (Jour. of Geol., vol. 5, pp. 653-683, Oct.-Nov. 1897.)

Clarke, J. M.

A sphinctozoan calcisponge from the upper Carboniferous of eastern Nebraska. (Am. Geol., vol. 20, pp. 387-392, pl. 23, Nov. 1897.)

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*This list includes titles of articles received up to the 20th of the preceding month, including general geology, physiography, paleontology, petrology and mineralogy.

Claypole, E. W.

Presidental address. Microscopical light in geological darkness. (25 pp.; reprinted from Trans. Am. Microscopical Soc., 1897.)

Coleman, A. P.

Third report on the West Ontario gold region. (Ontario Bureau of Mines, 6th [1896] Rept., pp. 71-124, 1897.)

Coleman, A. P.

Anthraxolite or anthracite carbon. (Ontario Bureau of Mines, 6th [1896] Rept., pp. 159-161, 1897.)

Cross, Whitman.

An analcite-basalt from Colorado. (Jour. of Geol., vol. 5, pp. 684-693, Oct.-Nov. 1897.)

Daly, R. A.

Studies on the so-called porphyritic gneiss of New Hampshire. (Jour. of Geol., vol. 5, pp. 694-722, Oct.-Nov. 1897.)

Davis, W. M.

The Harvard geographical models. (Boston Soc. Nat. Hist., Proc., vol. 28, no. 4, pp. 85-110, pls. 1-4, July 1897.)

Davis, W. M.

The present trend of geography. (Univ. of the State of N. Y., pp. 192-202, 1897. Paper read June 29, 1897, at the 35th Univ. Convocation.)

Dawson, G. M.

The physical geography and geology of Canada. (48 pp.; Toronto, Rowsell and Hutchinson, 1897. Reprinted from the Handbook of Canada, issued by the publication committee of the local executive of the British Association.)

Dixon, R. B. (and Drew, C. D.)

Observations on the physiography of western Massachusetts. (Science, n. ser., vol. 6, p. 847, Dec. 3, 1897.)

Drew, C. D. (Dixon, R. B. and)

Observations on the physiography of western Massachusetts. (Science, n. ser., vol. 6, p. 847, Dec. 3, 1897.)

Dumble, E. T.

Some Texas oil horizons. (Texas Acad. Sci., Trans. for 1897, vol. 2, no. 1., pp. 87-92, 1897.)

Dumble, E. T.

Texas Permian. (Texas Acad. Sci., Trans. for 1897, vol. 2, no. 1, pp. 93-98, 1897.)

Ellis, W. H.

Chemical composition of the anthraxolite. (Ontario Bureau of Mines, 6th [1896] Rept., pp. 162-166, 1897.)

Fairchild, H. L.

Glacial geology of western New York. (Geol. Mag., n. ser., dec. 4, vol. 4, pp. 529-537, pl. 21, Dec. 1897.)

Fraser, Persifor.

The seventh International Congress of Geologists. (Am. Geol., vol. 20, pp. 409-419, Dec. 1897.)

Frazer, Persifor.

Geological section from Moscow to Siberia and return. (Acad. Nat. Sci. Phila., Proc. 1897, pp. 405-457, 1897.)

Hill, R. T.

The alleged Jurassic of Texas. A reply to professor Jules Marcou. (Am. Jour. Sci., ser. 4, vol. 4, pp. 449-469, Dec. 1897.)

Holmes, W. H.

Primitive man in the Delaware valley. (Science, n. ser., vol. 6, pp. 824-829, Dec. 3, 1897.)

Jaggar, T. A., Jr.

A microsclerometer, for determining the hardness of minerals. (Am. Jour. Sci., ser. 4, vol. 4, pp. 399-412, pl. 12, Dec. 1897.)

James, J. F.

Manual of the paleontology of the Cincinnati group. Part VIII. (Jour. Cincinnati Soc. Nat. Hist., vol. 19, no. 3, pp. 99-118, Nov. 13, 1897.)

Kunz, G. F.

On the sapphires from Montana, with special reference to those from Yogo gulch in Fergus county. (Am. Jour. Sci., ser. 4, vol. 4, pp. 417-420, Dec. 1897.)

Leverett, Frank.

Changes of drainage in southern Ohio. (Bull. Sci. Lab. of Denison Univ., vol. 9, pt. 2, pp. 18-21, pl. 2, Mch. 1897.)

Lindahl, Josua.

Description of a Devonian ichthyodorulite, Heteracanthus uddeni, n. sp., from Buffalo, Iowa. (Jour. Cincinnati Soc. Nat. Hist., vol. 19, no. 3, pp. 95-98, pl. 6, Nov. 13, 1897.)

Logan, W. N.

Some new cirriped crustaceans from the Niobrara Cretaceous of Kansas. (Kans. Univ. Quart., vol. 6, pp. 187-189, Oct. 1897.)

Lyman, B. S.

Compass variation affected by geological structure in Bucks and Montgomery counties, Pa. (5 pp. and map: reprint from Jour. Franklin Inst., vol. 144, Oct. 1897.)

Marsh, O. C.

Recent observations on European dinosaurs. (Am. Jour. Sci., ser. 4, vol. 4, pp. 413-416, Dec. 1897.)

Martin, D. S.

Excursions of the recent International Geological Congress. (Appleton's Pop. Sci. Monthly, vol. 52, pp. 228-235, Nov. 1897.)

Osborn, H. F.

Wind River and Bridger beds in the Huerfano Lake basin. (Am. Nat., vol. 31, pp. 966-968, Nov. 1897.)

Palache, Chas.

The Geological Congress in Russia. (Am. Nat., vol. 31, pp. 951-960, Nov. 1897.)

Pirsson, L. V.

On the corundum-bearing rock from Yogo gulch, Montana. (Am. Jour. Sci., ser. 4, vol. 4, pp. 421-423, Dec. 1897.)

Pratt, J. H.

On the crystallography of the Montana sapphires. (Am. Jour. Sci., ser. 4, vol. 4, pp. 424-428, Dec. 1897.)

Prosser, C. S.

The Permian and Upper Carboniferous of southern Kansas. (Kans. Univ. Quart., vol. 6, pp. 149-175, pls. 18-19, Oct. 1897.)

Sardeson, F. W.

On glacial deposits in the Driftless area. (Am. Geol., vol. 20, pp. 392-403, Dec. 1897.)

Spurr, J. E.

The measurement of faults. (Jour. of Geol., vol. 5, pp. 723-729, Oct.-Nov. 1897.)

Tight, W. G.

Some preglacial drainage features of southern Ohio. (Bull. Sci. Lab. of Denison Univ., vol. 9, pt. 2, pp. 22-32, pls. 3 and A-C, Mch. 1897.)

Tight, W. G.

A preglacial valley in Fairfield county [Ohio]. (Bull. Sci. Lab. of Denison Univ., vol. 9, pt. 2, pp. 33-37, pls. 4 and D-F, Mch. 1897.)

Udden, J. A.

A brief description of the section of Devonian rocks exposed in the vicinity of Rock Island, Ills., with a statement of the nature of its fish remains. (Jour. Cincinnati Soc. Nat. Hist., vol. 19, no. 3, pp. 93-95, Nov. 13, 1897.)

Upham, Warren.

Drumlins containing or lying on modified drift. (Am. Geol., vol. 20, pp. 383-387, Dec. 1897.)

Weller, Stuart.

On the presence of problematic fossil medusæ in the Niagara limestone of northern Illinois. (Jour. of Geol., vol. 5, pp. 744-751, 1 pl., Oct.-Nov. 1897.)

Whiteaves, J. F.

The fossils of the Galena-Trenton and Black River formations of lake Winnipeg and its vicinity. (Geol. Sur. of Canada, Palæozoic Fossils, vol. 3, pt. 3, pp. 129-242, pls. 16-22, Apr. 1897.)

Williston, S. W.

Range and distribution of the mosasaurs, with remarks on synonymy. (Kans. Univ. Quart., vol. 6, pp. 177-185, pl. 20, Oct. 1897.)

Williston, S. W.

A new labyrinthodont from the Kansas Carboniferous. (Kans. Univ. Quart., vol. 6, pp. 209-210, pl. 21, Oct. 1897.)

CORRESPONDENCE.

THE MECHANICAL ACTION OF THE DIVINING-ROD. The review in *Nature* (Oct. 14th, 1897, pp. 568, 569) of a publication relating to the "divining rod" recalls to my mind a purely mechanical theory of that rod, which was given me years ago by a friend.

This theory has been repeatedly tested by me and shown to be correct in the presence of my classes.* The process is exceedingly simple. Take any forked twig of reasonably tough fibre in the clenched hands with the palms upward. The ends of the limbs forming the twig-fork should enter the closed fist on the exterior side of each fist, i. e., on the two sides of the clenched hands furtherest from each other.

When a twig is grasped in this position it will remain stationary if held loosely or with only a moderately firm grasp, but the moment the grasp is tightened the pressure on the branches will force the end of the twig to bend downwards. The harder the grip the more it must curve.

The curvature of the twig is mechanically caused by the pressure of the hands forcing the limbs to assume a bent and twisted position; or the force that causes the forked limb to turn downwards is furnished by the muscles of the hands, and not by any other cause.

The whole secret of the divining rod seems to reside in its position in the hands of the operator, and in his voluntarily or involuntarily increasing the closeness of his grasp on the two ends of the branches forming the fork.

If the above conditions are fulfilled, the twig will always bend downwards—water or no water, mineral or no mineral. Any one can be an operator, and any material can be used for the instrument, provided the limbs forming the fork are sufficiently tough and flexible.

It can be easily understood how an ignorant operator may deceive himself and be perfectly honest in supposing that some occult force, and not his hands, causes the fork to curve downwards.

Michigan College of Mines, Dec. 8, 1897. M. E. WADSWORTH.
Houghton, Michigan.

PERSONAL AND SCIENTIFIC NEWS.

New York Academy of Sciences, Section of Geology, November 15th, 1897.—The first paper of the evening was by Dr. F. J. H. Merrill, of the State Museum at Albany, entitled, "Geology of the Vicinity of Greater New York."

Dr. Merrill considered the distribution, relations and structure of the crystalline, metamorphic and intrusive rocks east of the Hudson.

He noted particularly in the vicinity of New York city the pre-Cambrian Fordham gneiss, overlain at certain places, as at Lowerre, Hastings, Sparta and Peekskill by a very thin bed of quartzite, probably representing the Georgian quartzite of Dutchess county. Above this is a thick series of crystalline limestones, forming the valleys of the Harlem, Bronx and other rivers, and underlying most of the navigable waterways in the vicinity of New York. The upper rocks are mica-schists which are probably of Hudson River age, and make most of the highlands of New York city and vicinity. These rocks are extensively folded in a general direction of N. 40 E., with occasional cross foldings, producing the cross valleys. The whole series is crossed by the Manhattanville fault, running from Manhattanville, North river, southeastwards to the East river, between Ward's and Blackwell's islands, into Astoria bay. This fault, along which there has been a throw of a number of hundred feet, was long ago described by Prof. Dana.

The second paper of the evening was by captain J. J. Riley, entitled, "The Guano Deposits of the Islands in the Southern Pacific, and Their Prehistoric Remains."

Dr. Riley considered in detail the depth, value and manner of working of the guano deposits in the Chincha islands, off the southern coast of Peru, from which guano was first taken by Humboldt in 1804, and which have since become very famous. Between 1850 and 1880, it is estimated that guano to the value of 550 million dollars in gold was taken from three islands alone. The islands lie in the rainless region, and the preservation of the guano is due to the absence of water. Once in about seven years there is a season of quite a little rainfall, which has undoubtedly a great effect upon the guano, and was considered by Capt. Riley to be the cause of the blacker bands in the layered deposits. Two burial tombs containing bodies of great antiquity have been discovered in the guano; the bodies were evidently of royal personages, and apparently, from the evidences of slabs containing certain symbols, related to the Incas. These tombs were found at a depth of 35 and 68 feet; but it is not possible to state whether they were buried in the guano, or later covered by it. The islands, three in number, are granitic in character, and were covered by a varying thickness of guano, reaching in the more important island a depth of 203 feet in places. The exportation of guano has, however, ceased since 1880.

In the discussion, Dr. Julien compared these islands with other guano-bearing islands of the West Indies, paying particular attention to the absence of any evidences of human remains showing life coincident with the formation of the guano.

The third paper, read by title, was by Mr. Stuart Weller, and entitled, "A New Crinoid in the Coal Measures of Kansas." Richard E. Dodge *Secretary*.

A new meteorite. Early in 1897 two pieces of meteoric iron, weighing sixty-two and fifty-one pounds respectively, were found three miles northwest of Mungindi postoffice, New South Wales, but really in Queensland territory. This meteorite, which is called the Mungindi meteorite (G. W. Card; Geol. Sur. N. S. Wales, Records, vol. 5, pt. 3, Sept. 1897), apparently fell some time ago as in places weathering has brought out naturally etched Widmanstätten figures. These

two pieces of iron are now in the mining and geological museum of New South Wales.

Rev. Dr. Samuel Haughton, formerly professor of geology in Trinity College, Dublin, died on Oct. 31.

Hon. Gardiner Greene Hubbard, pres. of the National Geographic Society, died at his home near Washington on Dec. 11, aged 75 years.

The Minnesota Academy of Natural Sciences held meetings in celebration of its twenty-fifth anniversary on Dec. 28, 29 and 30.

Mr. Waldemar Lindgren, of the U. S. Geological Survey, is to deliver a course of lectures on mining and metallurgy at Stanford University.

Mr. Edgar R. Cummins, of Cornell University, who graduated from Union College last June with honors in geology, has been appointed instructor in geology in the University of Indiana. (*Science.*)

Institute of France, Cuvier Prize.—At the session of the *Académie des Sciences* held at Paris, Dec. 13, 1897, the Cuvier prize of 1,500 francs was awarded to professor O. C. Marsh, of Yale University. This prize "is awarded every three years for the most remarkable work either on the animal kingdom or on geology."

Rev. Peter Bellinger Brodie, an English geologist, died on Nov. 1st. He early manifested an interest in geology, which was fostered at Cambridge, where he studied under Sedgwick. Mr. Brodie was elected a fellow of the Geological Society of London in 1834 and in 1887 that society conferred upon him the Murchison medal. The November number of the Geological Magazine contains a sketch (with portrait) of Mr. Brodie, written shortly before his death.

The Iowa Academy of Sciences held its twelfth annual meeting at Des Moines on December 27 and 28. The following geological papers were presented:

Is the loess of aqueous origin? B. Shimek.
The degradation of the loess. J. E. Todd.
Sketch of the hydrographic history of South Dakota. J. E. Todd.
Carboniferous formation of the Ozark region. C. R. Keyes.
Geographic development of the Crimea. C. R. Keyes.
Some geological features of the Cap au Gres region. C. R. Keyes.
Some anomalous valleys and paradoxical divides in Delaware county, Iowa. Samuel Calvin.
Interglacial deposits of northwestern Iowa. Samuel Calvin.
The buried soil between the Iowa loess and the Illinois till sheet. Frank Leverett.
Aftonian deposits of southwestern Iowa. H. F. Bain.
Preglacial peat beds. J. A. Udden.
The drift section and the glacial striæ in the vicinity of Lamoni. T. J. Fitzpatrick.

Fig. 1.

Fig. 2.

THE

AMERICAN GEOLOGIST.

VOL. XXI. FEBRUARY, 1898. NO. 2

ADDITIONAL NOTE ON THE OCEANIC CURRENT IN THE UTICA EPOCH.

By R. RUEDEMANN, Dolgeville, N. Y.

(Plate IX.)

In an article, published in the June (1897) number of this journal,* the writer described a series of observations which led him to suppose the existence of an ocean current in the Utica epoch in the south and southwest of the Archæan mass of the Adirondacks. The evidence of the oceanic motion consists mainly in the parallel arrangement of graptolites and cephalopods in a NE-SW direction in the Utica shale, in outcrops occurring in the Mohawk valley and on Nine-Mile creek, north of Utica.† The observed directions in the last locality, which is southwest of the crystalline area, necessitate the assumption that the southern part of the latter was a peneplain, which was swept by the current, and that the mantle of Utica shale formely extended considerably farther north than it does at present.

C. D. Walcott‡ reached the conclusion before, that the Cambrian-Ordovician sea spread over the Adirondack crystallines, depositing a mantle of sediments. This supposition is illustrated by an ideal section (p. 25), in explanation of which is said:

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*Vol. XIX, No. 6, p. 367.

†Cf. the sketch map, op. cit. pl. XXII.

‡Second Contribution to the Studies on the Cambrian Faunas of [illegible]th America, Bull. of the U. S. Geol. Survey, No. 30, 1886, p. 24.

"The view expressed by the section is that there was a practically conformable deposition of sediments, against and over the Archæan area of the Adirondack mountains, from early Cambrian times up to the close of the deposition of the sediment forming the Utica shale, except in the case of the unconformity by non-deposition between the Potsdam and the Chazy. The writer has seen the deposition contact of the Utica shale, against the granite, on the eastern side of the Adirondack mountains, in Essex county, New York, and takes that as the upper line of the ideal section, although he has little doubt that the formations overlying the Utica shale, even through the Silurian, were deposited against and over the Archæan of the Adirondacks and subsequently removed by denudation."

Lately a somewhat different view regarding the relation of the sedimentary covering to the underlying crystallines has been advanced by J. F. Kemp.*

A careful study of the topography and geology of the outliers in the eastern Adirondacks led Mr. Kemp to the conclusion that the Palæozoic rocks—Potsdam sandstone and Calciferous limestone at present, and also Trenton and Utica beds formerly, as Mr. Kemp supposes—were deposited in preexisting valleys, which had been formed when, in the early Cambrian, the Adirondack hight-of-land must have been subjected to the ordinary processes of erosion and land sculpture. Mr. Kemp admits that faulting no doubt plays a considerable part in many of the outliers, but, at the same time, calls attention to the fact that some of the present streams, connected with the outliers show often very low gradients for Adirondack creeks and appear to be near local base levels. It is supposed that the post-palæozoic erosion, as well as the great ice-sheet, were active in clearing the valleys of the Cambrian and Ordovician sediments, and in reducing them to their pre-Cambrian gradients.

Special attention is also called in Mr. Kemp's interesting paper to the outlier of Palæozoic rocks at Wellstown, on the Sacandaga river.† As this remarkable outlier, which consists of Potsdam, Calciferous, Trenton and Utica beds, lies directly in the path of the current which produced the parallel arrange-

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*J. F. Kemp. Physiography of the eastern Adirondacks in the Cambrian and Ordovician times. Bull. Geol. Soc. Am., Vol. VIII, p. 408, 1896, and J. F. Kemp. The Pre-Cambrian Topography of the Eastern Adirondacks, read at the Washington meeting of the Geol. Soc. Amer.; Abstract in Jour. Geol., Vol. V, No. 1, p. 101, 1897.

†See the map: Am. Geol., Vol. XIX, No. 6, pl. XXII.

ment of the fossils on Nine-Mile creek, the writer had made use of its existence to prove the submergence of the southern Adirondacks in the Utica epoch. It is evident that if this outlier is only to be regarded as the remnant of a deposit in a drowned valley, the assumption of the passing of a current across the Adirondacks as far north as Trenton Falls, is not justified.

The outlier at Wellstown, which had been discovered and described by Vanuxem in 1842, has been lately described more fully by N. H. Darton.* It appears from the latter investigator's description, that "the area of Palæozoic rocks was found lying against a fault scarp on its western side, and possibly faulted on the east side also," and that the Potsdam, Calciferous, Trenton and Utica formations have their usual characteristics, and the latter two, their usual faunas. Thus, the interesting fact that four different beds belonging to different periods occur in the same small outlier, in a remote place in the Adirondacks, is rendered still more remarkable by the observation that all these beds apparently differ in no way from the continuous terranes along the southern border of the Archæan area. These remarkable features of the outlier and the importance of the knowledge of its origin for the writer's views on current action in the Utica epoch, induced him to visit the locality.

The outlier was found to form an oblong plain surrrounded on all sides by steeply rising ridges of crystalline rocks. The fault-scarp at the west side is distinct, the Archæan rocks rising steeply 1,300 feet above the Potsdam level. As also on the east side, the Archæan hills present a steeper slope than the but slightly tilted Palæozoic rocks which outcrop at their base, the existence of a fault is very probable also on this side. The whole outlier, therefore, seems to be the remnant of a fault-valley or "graben." This fault-valley has, however, been formed after the deposition of the Palæozoic strata, and served only to protect them from the destructive effects of the atmosphere and of glaciers. Originally, the beds belonged to a continuous mantle of Palæozoic strata, which covered the south-

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*Geology of the Mohawk Valley. Rept. of N. Y. State Geologist for 1893, pp. 414 and 429. See also: A Preliminary Description of the Faulted Region of Herkimer, Fulton, Montgomery and Saratoga Counties. Rept. of N. Y. State Geol. for 1894, p. 47.

ern flank of the Archæan mass. The main argument for this supposition is that the Potsdam, Calciferous. Trenton and Utica formations, are developed here in a like manner as the respective strata which, in the south, strike continuously along the foot of the Adirondacks. The Potsdam—consisting of a rusty weathering, not very coarse grained, somewhat calcareous sandstone, that alternates with lighter colored beds—and the light-colored arenaceous limestone that represents the Calciferous, differ in no way from the outcrops in the Mohawk valley. The Utica shale, which is well exposed in a pit for breaking road-metal, and which outcrops in a neighboring rivulet in several places, is the typical, fine-grained, often fissile black shale of the lower part of the formation and contains scattered specimens of Diplograptus foliaceus Murch. (= pristis Hall). A slab in the ravine contained a greater number of these graptolites, which were arranged between N 50 degrees E and N 90 degrees E. In slabs found on a road, fragments of Endoceras and casts, probably belonging to a Modiolopsis, were met with. Neither does the light-gray, highly fossiliferous limestone, which, for many years, has been used for lime-burning, differ from the Trenton in the Mohawk valley. The only remarkable feature is a bed which contains round pebbles of a few inches diameter, and which are derived from a lower part of the limestone. But such conglomerates occur even much farther south in the Trenton. They are of general interest, as the Trenton limestone has been often regarded,* and not without good reason, as a deep-water deposit. A very interesting occurrence of conglomerate in the Trenton was found by the writer at Ingham's Mills, on East Canada creek, in an exposure, which has been made known by N. H. Darton.†

The slaty intercalation in the upper eight feet of thin-bedded limestone, near the top of the section, was here found to contain water-worn, rounded, flat boulders,‡ which reach a diameter of several feet and are derived from the light-colored compact layers below the typical Birdseye limestone. As the

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*Compare for instance Lapworth, Trans. Roy. Soc. Can. for 1886, V, Sec. IV, p. 176.

†Geology of the Mohawk Valley, Rept. of N. Y. State Geologist for 1893, p. 422.

‡See Plate IX, fig. 2.

pebbles at Wellstown and at Ingham's Mills consist only of limestone, and not of crystalline rocks they indicate but a temporary recession in the Trenton epoch, during which some of the lower limestone was worked up. It is, however, remarkable that this limestone had already hardened.

The conclusion to be drawn from the comparison of the four Palæozoic terranes at Wellstown, and in the lower Mohawk valley, is that equal conditions existed at both places during each of the four periods. The deposits in the Mohawk valley are evidently those of an open, unbroken seacoast, and it is a recognized fact that different sediments are deposited in embayments and in the open sea. The exceptional case of the deep fjords of Norway, which partly show the fauna and deposits of the deeper part of the North sea off the coast of Norway, can hardly be adduced here. Moreover, it can hardly be assumed that the successive changes in character of sediment, taking place from the Potsdam through the Calciferous and Trenton to the Utica formations, should have been exactly repeated in a bay which, being formed by the drowning of a valley, could not have been very wide, and, lastly, it must be expected that the upper course of the Sacandaga river, which emptied in that bay, would have filled it with deposits of crystalline origin.

The writer's view, that the Utica shale at Wellstown is only a remnant of a once continuous covering of the southern Adirondacks, seems also to be supported by the great number of fragments of Utica shale and the great quantities of dark clay with included shale in the glacial drift on the southern slope of the Adirondacks. The amount of this drift would seem to indicate the scouring away and working up of more shale than the valley deposits could have furnished, and it can hardly be assumed that the fissile, easily ground shale could have been brought from the northeast and carried over the Archæan area.

All these conclusions refer only to the outlier at Wellstown and to the southern slope of the Adirondacks, those in the east of this plateau not being known to me.

The writer embraces this occasion to correct an oversight, committed in the first paper on current action, by not mentioning the interesting conclusions of G. F. Matthew on the

distribution of animals in Cambrian and Ordovician times. Mr. Matthew,*in an address on the "Diffusion and Sequence of the Cambrian Faunas," comments upon the deep-sea character of the various graptolitic faunas, as expressed in the composition of graptolites, Triarthrus, deep-water sponges, and brachiopods. The graptolitic faunas are enumerated, the last being that of the Utica slate. In reference to this is related that after the irruption of the Arenig fauna and the following restoration to more genial conditions in the beginning of the Trenton period, a new fauna invaded the territory held in the east by the Trenton fauna, that of the Utica slate. This fauna succeeded in extending itself further west than its predecessors of the Atlantic coast containing graptolites. Besides occupying the St. Lawrence valley, it was spread westward across the provinces of Quebec and Ontario, and southward through New York and Pennsylvania. In contrasting the slow migration of shallow water forms with that of the inhabitants of the deeper and colder sea, the following statement is made: "No sooner do the latter appear in Europe than almost simultaneously we find them (or species closely related to them) on the Atlantic coast of the new world." This implies the assumption of a migration of the deep-water forms, characteristic of the Utica shale, from Europe to North America.

The same idea is still farther developed in another address,† in which Mr. Matthew contrasts the faunas of the warm and shallow water with those of the colder and deeper water, and concludes that the coralline limestones represent the preponderance of warm shallow water, the graptolitic mud deposits representing the deeper and colder parts of the ocean. Applying this principle to the succession of calcareous terranes, containing corals and large mollusks, and of the different graptolitic shaly terranes of the North American Cambrian and Ordovician, Mr. Matthew concludes that this succession was caused by alternating incursions of deep cold water faunas from Europe, and of warm shallow water faunas from the American Mediterranean sea. Two sketch maps

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*Published in: Trans. Roy. Soc. Canada. Vol. X, Sec. IV, 1892, p. 3.

†The Climate of Acadia in the Earliest Times. Annual Address. Bull. Nat. Hist. Soc. New Brunswick, No. XI, 1893, p. 3.

serve to illustrate these successive arrivals of faunas of different origin in the northeast of North America.

While thus the Trenton contained a warm water fauna, which had its origin in the southwest, the Utica fauna was borne to us on the cold current from north Europe, where it probably had its fountain-head, as the Paradoxides and Arenig faunas had before. It is obvious that these interesting conclusions of Mr. Matthew as to the origin of the Utica fauna find a verification in the writer's observations on the existence of an ocean current passing from northeast to southwest along the south slope of the Adirondack Archæan area in the Utica epoch. The writer had supposed that this current had taken the course of the present Labrador current, and followed the east coast of the Laurentian continental nucleus of Canada.

EXPLANATION OF PLATE.

Fig. 1. Section at Ingham's Mills:

(a). Eight feet of Trenton limestone and intercalated slate, the latter containing limestone bowlders.

(b). Typical Birdseye limestone, the vertical columnar fucoidal stems, producing the birds' eyes on the bedding planes, are visible on the photograph.

Fig. 2. Conglomerate, showing the contorted shale and the imbedded limestone bowlders.

[European and American Glacial Geology Compared, I.]

SHELL-BEARING DRIFT ON MOEL TRYFAN.

By Warren Upham, St. Paul, Minn.

This series of short papers is designed to describe briefly the glacial geology of some important or especially interesting European areas, or localities, examined by the writer during the summer of 1897, and to compare them with similar American glacial observations and theories.

Landing in Southampton June 2nd, our party, including also my wife and a lady friend, spent the next eight days in London, Oxford, and Stratford-on-Avon. June 11th we went onward by way of Chester, the north shore of Wales, and Carnarvon, to Llanberis, a pretty village in a very picturesque valley at the north base of the craggy, sharp-peaked Snowdon

and the rounded, grassy Moel Eilio (2,382 feet). The next day we ascended Snowdon by its railway, rising from the lakes of Llanberis (400 feet above the sea) to the highest summit of southern Britain, 3,570 feet above the sea. Around us, on all sides excepting northwestward, were the steep, mostly rugged and boldly serrate Welsh mountains, consisting of the very ancient Cambrian rocks.

Moel Tryfan (or Tryfaen), the hill which for that day was my desired destination, lay in plain view at a distance of six miles westward, beyond a deep valley in which we saw the Cwellyn lake (about 500 feet above the sea) and the Snowdon Ranger inn, with its group of Scotch pines. Toward the drift sections displayed in the slate quarrying near the top of that hill, visited and much discussed by many geologists during the past sixty years, I walked down the stony path to the inn, past the lake, beneath the northern precipice of a spur of Mynydd Mawr, and up the drift-covered, smooth and pastured ascent of Moel Tryfan. Looking back, I saw a cloud bank enveloping the top of Snowdon and towering above to a great altitude, though elsewhere the air and sky were mostly clear.

The area occupied by Moel Tryfan is about a mile in diameter. Its slopes, of moderate steepness, are almost wholly covered by till, with frequent or abundant boulders, beneath which, at the quarries, are extensive deposits of gravel and sand. At shallow depths the slate is reached and quarried; and at the summit a jagged mass of conglomerate juts up about 15 feet above the surrounding grassy pasture. The hight of this point is given on the Ordnance Survey map as 1,399 feet above the sea. The highest col dividing this hill from the neighboring mountains is on the southeast, at a distance of about a mile, having an estimated altitude of about 1,150 feet, whence the next mile eastward rises to the crest of Mynydd Mawr, at 2,290 feet. On the southwest and thence around to the north, all the country is much lower than our hill, and is a fine agricultural district, with the little seaport city of Carnarvon well seen four miles northwest.

In 1831, Trimmer discovered fragmentary marine shells in the sand and gravel under the superficial boulders and till at the slate quarries near the top of Moel Tryfan; and by sub-

sequent collectors about 60 marine species have been found in these sections, from about 1,275 to 1,360 feet above the sea, including 27 lamellibranchs, 26 gastropods, two species of Dentalium, two of barnacles, one Serpula, and two species of the shell-burrowing sponge, Cliona.[*] In 1842, Darwin observed that the underlying slate, "to a depth of several feet, had been shattered and contorted in a very peculiar manner." In 1863, Lyell noted that he saw in the lower beds of the shell-bearing sand and gravel several large boulders of far-transported rocks glacially polished and scratched.

Among the great number of geologists who have treated more or less fully of this fossiliferous drift we may further especially mention Reade,[†] Shone,[‡] Mackintosh[§] and Strahan.[||] All these authors refer the deposition of the shell-bearing stratified drift to marine action during a time when northern Wales, with Cheshire, Lancashire, and other parts of northwestern England, and a part of Ireland, near Dublin, if not much greater areas, suffered a depression of 1,000 to 1,360 feet or more. In these districts various localities have been discovered where fragments of marine shells occur in the modified drift up to these altitudes, their maximum hight being on Moel Tryfan.

Other geologists, as Belt and Goodchild in 1874, H. Carvill Lewis in 1886, and Percy F. Kendall in 1892, have attributed these shell-bearing beds to deposition from the streams of the melting British ice-sheet, while the land here stood at nearly its present level, during the Champlain or closing epoch of the Glacial period.[¶] This view seems to me

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[*] J. Gwyn Jeffries. Quart. Jour. Geol. Soc., XXXVI (1880), 351-355. T. McKenny Hughes, in the same Journal, XLII (1887), 87-97, gives tabular enumerations of the marine fossils in the drift of Moel Tryfan (66 species) and of numerous other localities and districts of northern Wales and northwestern and northeastern England, with bibliography.

[†] Q. J. G. S., XXX (1874), 27-42; XXXIX (1883), 83-132. Proc., Liverpool Geol. Soc., 1892-93, pp. 36-79, with eight plates (maps and sections) and a bibliography.

[‡] Q. J. G. S., XXXIV (1878), 383-397.

[§] Id., XXXVII (1881), 351-369; XXXVIII (1882), 184-196.

[||] Id., XLII (1886), 369-391 [abstract in Geol. Mag., third series, III, (1886), 331-333].

[¶] See the present writer's sketch of "Prof. Henry Carvill Lewis and his Work in Glacial Geology." Am. Geologist, II, 371-379, Dec., 1888; and Kendall's admirable summary of the glacial geology of England and Wales, in Wright's "Man and the Glacial Period," 1892, pp 137-181, with maps and sections.

the true explanation. It regards the shell fragments as derived by glacial transportation from the area of the Irish sea, by an ice-sheet flowing southward from southwestern Scotland, northwestern England, and northeastern Ireland, by which the early Pleistocene beds of that sea basin were plowed up and mingled with boulders from the more distant northern tracts of thick ice accumulation. Many of the boulders, with much finer drift, were derived from mountains high above the old sea bed; but I think that drift from all these sources, both high and low, was intermingled in the lower part of the moving ice-sheet, up to hights of probably 1,000 to 1,500 feet in the ice, and yielded to the streams of its final melting the shell-bearing gravel and sand of these high levels, as also of lower tracts down to the present coast lines.

Jeffreys states that eleven species of the Moel Tryfan marine shells are arctic or northern, of which eight now range no farther south than the coasts of Norway, there living at depths of from 10 to 20 fathoms; but that the other species (a large majority of the whole) are littoral or live in shallow water, all of these being probably now inhabitants of the neighboring Carnarvon bay.

With slight search I found in the sand and gravel on the northwest side of the Alexandra slate quarry, about 50 feet below the rock peak of Moel Tryfan, many minute particles of shells, from the size of a pinhead to an eighth or a quarter of an inch, and a few larger fragments, referred to three species, as determined by Prof. Kendall, namely Leda pernula Müller, Tellina balthica L., and Fusus antiquus L., the last having its Pleistocene dextral form, distinguished thus from its uniformly sinistral Pliocene form.

The Alexandra quarry, about 30 rods in diameter, having a depth of 75 feet or more below the lowest northeastern part of its rim and fully 150 feet below the high western part of the rim, is situated about an eighth of a mile east from the summit of Moel Tryfan which rises some 40 feet above the highest part of the brink of this quarry. The eastern half of the rim or brink has much till, to the depth of 10 to 15 feet, inclosing plentiful boulders up to five feet and rarely ten feet in diameter. Beneath this till on the southeast are a few feet of very irregularly stratified and contorted sand and gravel,

which at the northeast increase to a thickness of about ten feet. Proceeding thence westward along the north rim of the quarry, the till gradually thins to only two or three feet, while the sand and gravel continue from 10 to 15 feet thick upon the rising slope of the slate. Along the western and southwestern sides the drift capping the vertical quarry walls maintains a thickness of from 12 to 18 feet, and is almost wholly sand and gravel, often contorted in bedding, with occasional stones up to a foot in diameter, especially in the upper one to four feet, while the adjoining surface bears frequent boulders.

Another quarry, of similar area and depth, has its northern brink only 40 feet south of the southern brink of the foregoing. Its slate is overlain around all its extent by 5 to 15 feet of drift, thickest at the northeast. This drift has mainly the stratification and other characters noted on the western half of the Alexandra quarry; but it includes, on the northeast, a thickness of several feet of overlying till. Superficial boulders are seen here and there on all the surrounding pasture land.

From my studies of the till of drumlins in and adjoining Boston harbor, containing plentiful fragments of marine shells which represent 55 species, all now living on our coast, but some having mainly a southern range,* and from my discovery of similar shell fragments in the modified drift forming Cape Cod,† I conclude that the modified drift and worn and broken marine shells of Moel Tryfan were supplied by the melting of the southern border of the principal British ice-sheet. In its maximum extent, that ice flow from the north abutted against local icefields that flowed outward from the Snowdonia mountain region. Their line or belt of junction appears to have crossed Moel Tryfan, and eastward to have passed over Fridd Bryn Mawr, which extends north from Moel Eilio along the west side of Llanberis and lake Padarn. On this Bryn Mawr, at the hight of about 1,000 feet above the sea, Ramsay found marine shell fragments in the drift.

More explicitly to indicate the conditions which seem to me to have attended the deposition of the Moel Tryfan sand

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*Proc., Boston Soc. Nat. Hist., XXIV, 127-141, Dec., 1888 (also in Am. Jour. Sci., III, XXXVII, May, 1889). W. O. Crosby and H. O. Ballard, Am. Jour. Sci., III, XLVIII, 486-496, Dec., 1894.

†Am. Naturalist, XIII, 489-502, 552-565, Aug. and Sept., 1879.

and gravel and the overlying till, I can do no better than to refer to my paper in the last number of this magazine, and to my description there cited of the occurrence of abundant stratified deposits under till in the basin of Lake Winnipesaukee in New Hampshire.* On Moel Tryfan free drainage carried away the clay and fine silt that were supplied to the waters of the glacial melting, and these waters appear to me to have deposited subglacially the shell-bearing gravel and sand, while the almost contemporaneous till was allowed to fall from its previously englacial and superglacial position when the ice was fully melted away.

The contour and surface deposits of this hill have no features which I can regard as suggestive of shore lines or of marine deposition or erosion.

COTE SANS DESSEIN AND GRAND TOWER.

By C. F. Marbut, Columbia, Mo.

(Plate X.)

Cote Sans Dessein is a narrow isolated ridge of paleozoic rocks rising steeply from the level of the flood plain of the Missouri river in the southeastern part of Callaway county, Missouri. It is about a mile long, 200 feet wide and rises 100 feet above the level of the flood-plain. The latter, at this place, is about two miles wide, and Cote Sans Dessein stands about midway between the northern and southern bluffs.

It is made up of horizontal beds of magnesian limestone, identical in age, structure and lithologic character with those outcropping in the bluffs on both sides of the flood-plain in the vicinity. The Missouri river now flows between Cote Sans Dessein and the southern border of the floodplain and has occupied this position continuously since the occupation of the region by white men; but the broad belt of typical flood-plain lying to the north of the hill is positive evidence that the river has recently occupied that belt.

Grand Tower is another hill whose relations to the flood-plain of the Mississippi river are apparently the same as those

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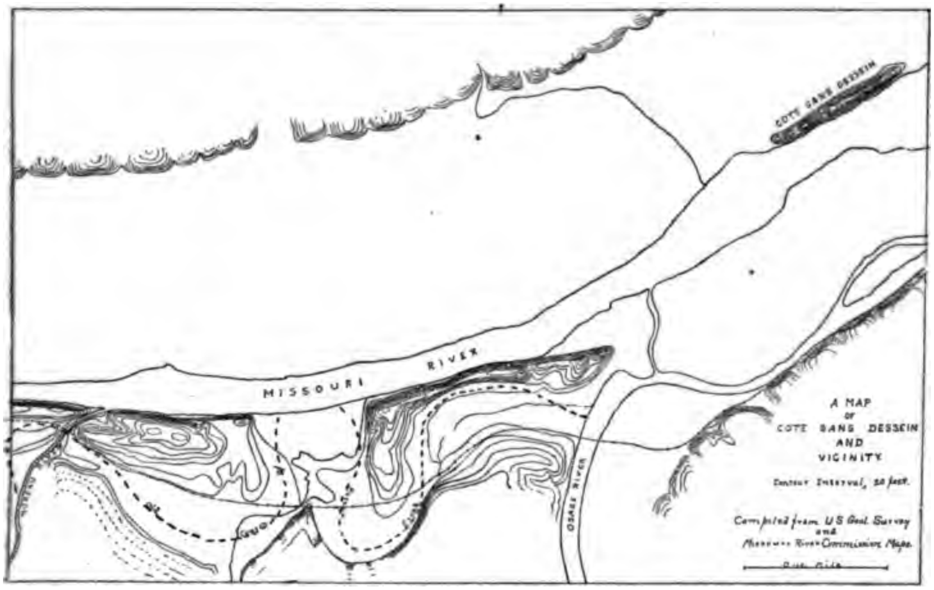
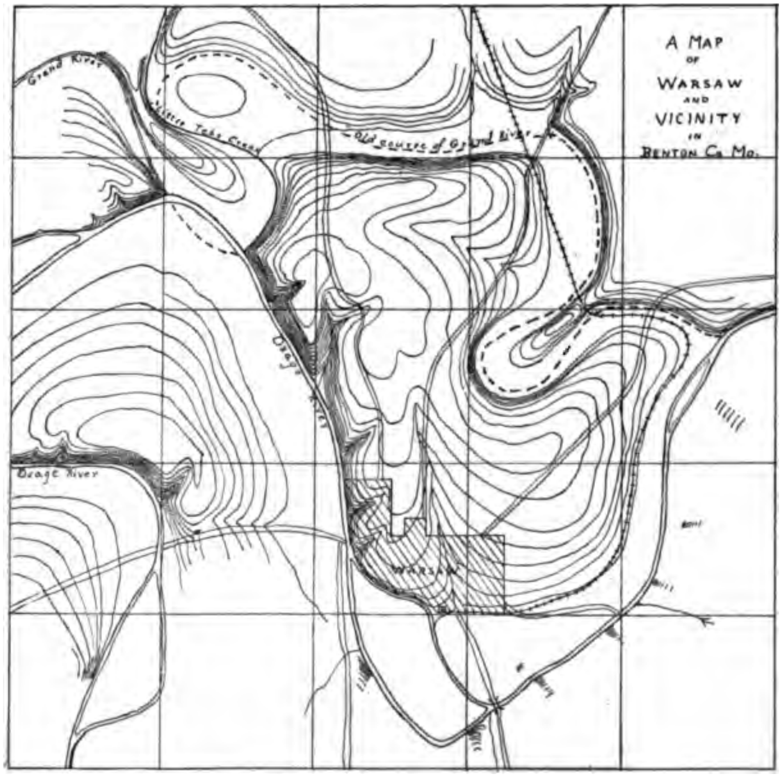
*Am. Geologist, XX, 383-387, Dec., 1897. Geol. of N. H., Vol. III, 1878, pp. 131-137.


COTE SANS DESSEIN
MISSOURI RIVER
OSAGE RIVER
A MAP
OF
COTE SANS DESSEIN
AND
VICINITY
Contour Interval, 20 feet.
Compiled from U S Geol. Survey and Missouri River Commission Maps.
One Mile


A MAP
OF
WARSAW
AND
VICINITY
IN
BENTON Co. Mo.
Grand River
Little Tebo Creek
Old course of Grand River
Osage River
Osage River
WARSAW

of Cote Sans Dessein to the Missouri river flood-plain. It is situated in Jackson county, Illinois, about 30 miles below Chester and about the same distance above Cape Girardeau. Like Cote Sans Dessein it is an isolated hill made up of beds of paleozoic rocks identical in age, structure and character with those exposed in the bluffs on both sides of the flood-plain. It rises abruptly above the flood-plain to a hight of fully 100 feet. It is accompanied by an unnamed companion, of about equal size and identical relations to surroundings, which lies about a mile to the north. Grand Tower differs from Cote Sans Dessein, however, in its position within the flood-plain. That part of the plain lying between Grand Tower and its eastern bluff is nearly five miles wide, while that part lying west of Grand Tower is less than two miles in width. The river at the present time occupies the belt between Grand Tower and the western bluff.

These features are members of a rather large group of hills, occurring in many parts of the world, which are more or less closely related to each other in origin. The greater number of them, however, are surrounded by narrow winding belts of lowland, while the two under consideration rise from the midst of wide lowlands. The origin of the former is now well understood and they have been described from many parts of the world.* They are known to be the result of the formation of cutoffs in upland meandering streams and are the homologues of the lands surrounded by crescentic lakes so common in the flood-plains of many large rivers. Hills of this kind occur in Missouri, but so far as now known they are confined to the streams of the Ozark region. They are known to occur on the Meramec, Bourbeuse, Grand and Gasconade rivers and on many small creeks. They do not occur on either the Missouri, Mississippi or the Osage. In Europe they are of frequent occurrence, especially in the Ardennes region of Belgium, the lower Seine region in France and in central Russia.

Cote Sans Dessein and Grand Tower show no evidence of such an origin. In fact, in the case of the former, the evidence of origin by different, though related process is clear. Its re-

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*Natl. Geographic Magazine, June and July, 1896.

lation to the Missouri and Osage rivers shows that it is an outlying remnant of the upland lying between the Osage and Missouri rivers. The Osage originally entered the Missouri below the lower end of Cote Sans Dessein. Subsequently, by the combined sapping of both the Missouri and Osage rivers on opposite sides of 'this upland it was cut through above Cote Sans Dessein. At that time or later the Missouri appropriated the lower part of the old Osage valley. Since doing this it has doubtless widened this belt so that it is now as wide as the old Missouri valley north of the hill. Cote Sans Dessein lies directly in the line of prolongation of this upland where it still exists. The meander system of both the Osage and Missouri rivers shows also that the point where the upland was cut was exposed to the vigorous sapping of both streams, being on the convex sides of meanders in both streams. Cote Sans Dessein stands where the meandering of the Osage at least carried the point of active sapping to the southern side of the valley.

Grand Tower maintains the same relation to the Mississippi and Big Muddy rivers that Cote Sans Dessein maintains to the Osage and Missouri. It is not so clearly due to this relation, however, as is Cote Sans Dessein. There is a very great difference in size between the Mississippi and Big Muddy. The latter is much smaller than the Osage, but that part of the flood-plain lying on the Big Muddy side of Grand Tower is much wider than the other. It may be true that the Mississippi was diverted to the Big Muddy valley soon after reaching grade and remained in that position until recently. The explanation of its existence is based wholly on its position with respect to the two streams.

The same processes have been operating in at least two other places in Missouri. One place is in the vicinity of the mouth of Moreau river, which flows into the Missouri about four miles above the mouth of the Osage. The Moreau was originally tributary to the Osage, entering the latter stream near the Missouri Pacific railway bridge. From that point up to its present mouth its general course was parallel to that of the Missouri, but instead of taking this course in a direct line it meandered over a belt more than a mile in width. Its own action on the convex side of the meanders combined with

the southward sapping of the Missouri, finally cut through the upland between the two streams, at a point about two miles above its old mouth. It then flowed into the Missouri and abandoned the lower part of its old valley. The Missouri river has never occupied this old valley as it has the old Osage valley south of Cote Sans Dessein. At a later period the Moreau again cut through the intervening highland between its valley and that of the Missouri and now enters that stream a little more than a mile above the first cut. At this point, however, the Moreau did not cut directly through the upland and into the Missouri flood-plain, but cut into and occupied the lower part of the valley of a small tributary of the Missouri. The tributary did not flow at right angles to the course of either the Missouri or the Moreau, but at a rather low angle with the latter for several hundred feet on each side of the point of capture. The Moreau began by capturing the headwaters of the small stream. It continued to invade more and more of the valley of the small stream until it had reached a point where the level of the latter was the same as that of the Moreau. The valley of the small stream was occupied and the Moreau abandoned another section of its former valley.

There can be no doubt that the abandoned valley is that of the Moreau. It is continuous with the present valley and of about the same width. The meanders of the old valley fit onto those of the Moreau, and the character of the meanders is the same in both cases. The Moreau is characterized by long swinging meanders with narrow belts of upland between, and a meander belt more than a mile in width.

Another repetition of the same features occurs in Benton county. Grand river, which flows into the Osage about three miles above Warsaw is a stream whose lower course, that through the lower Carboniferous and Silurian limestones, is very much like that of the Moreau. The present mouth of Grand river is the homologue of that of the Moreau after the first and before the second capture. In this case, however, the Osage river, the larger stream, did a relatively larger part of the work than did the Missouri in the other. Before this capture Grand river flowed into the Osage about three miles above ~~below~~ the present site of Warsaw. As in the case of the Moreau, the character of the abandoned part of Grand river valley leaves no doubt of its origin and for the same reasons.

Little Tebo creek, which was formerly tributary to Grand river, now flows into the Osage, reaching the latter by flowing up the abandoned valley for about a mile and a half. Another small stream, formerly tributary to Grand river at a point about two miles below the old mouth of Little Tebo, is now a tributary of the latter, turning up the old valley rather than down it. This stream could reach the Osage in just about the same distance that i~~t~~ now flows to reach it, by turning down the old valley. t/

THE GEOLOGY OF THE KEWEENAWAN AREA IN NORTHEASTERN MINNESOTA.

By A. H. Elftman, Minneapolis.

(Plate XI.)

SYNOPSIS.

Part I.—*Glacial Geology.*

General statement, moraines, non-morainic till, modified drift, wind deposits distribution of boulders, glacial striæ, glacial lakes and rivers, glacial erosion.

Part II.—*Geology of the Keweenawan Series.*

Chapter I.—Stratigraphy.
  1. Historical review.
  2. Results of the present investigation.

Chapter II.—Faulting in the Keweenawan Series.

Chapter III.—The Gabbro Group.
  Surface area, age, structure, differentiation varieties, mineral and chemical composition, contact phenomena.

Chapter IV.—The Beaver Bay Diabase Group.
  1. Diabase, diabase porphyrite, etc.
  2. Anorthosytes of the north shore of lake Superior.
  3. Fragmental rocks.

Chapter V.—The Red Rock Group.
  1. Intrusive; granite and augite syenite.
  2. Surface flows; quartz-porphyry, aporhyolite.

Chapter VI.—The Temperance River Group.
  1. Unconformity.
  2. Surface flows; diabase, etc.
  3. Intrusive,
  4. Sedimentary; conglomerate, sandstone, etc.

Chapter VII.—The Later Diabase Group.
  Dikes, sills, breccia.

Chapter VIII.—Summary and discussion.

PART I.

GLACIAL GEOLOGY.

General Statement.—Certain important features of the glacial geology of northeastern Minnesota are found within the areal limits of the Keweenawan series. The glacial drift occurs in: 1st, well defined moraines; 2nd, rolling till, and 3rd, modified deposits. The chief moraines are limited to the central part of this region, extending from Pigeon river to Saint Louis river, with the northern and southern boundaries of the morainic area equi-distant between the international boundary and lake Superior. The till and modified drift is abundant, and hence in this area the underlying rock is for the most part concealed, appearing only in isolated outcrops often several miles apart. In the rest of the region the drift is either present in small quantities occupying the depressions and covering the rocks with a thin veneer only, or it is entirely wanting. The drift of northeastern Minnesota is regarded as belonging to the Wisconsin stage of the Glacial Epoch.

MORAINES.

Mr. Warren Upham has mapped the moraines of northern Minnesota in the twenty-second annual report of the Minnesota Geological and Natural History Survey, plate I. In that portion of the state north of lake Superior widely separated known areas of morainic drift were provisionally correlated by Mr. Upham with the Leaf Hills, Itasca, Mesabi and Vermilion moraines found in the central and western parts of the state. The moraines thus mapped extend in a general east and west direction across Minnesota and appear to have been formed successively during a movement of the ice sheet principally from the north.

Prof. J. E. Todd has called attention to several objections to this interpretation;* namely, that the interpretation of Mr. Upham does not duly recognize the altitude and that it does not represent the ice sheet as retiring in the proper direction to explain the formation of Western Superior glacial lake, and that it does not agree with the direction of the striæ and

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*Revision of the moraines in central Minnesota. AMER. GEOL., vol. XVIII, 1896, pp. 225-226.

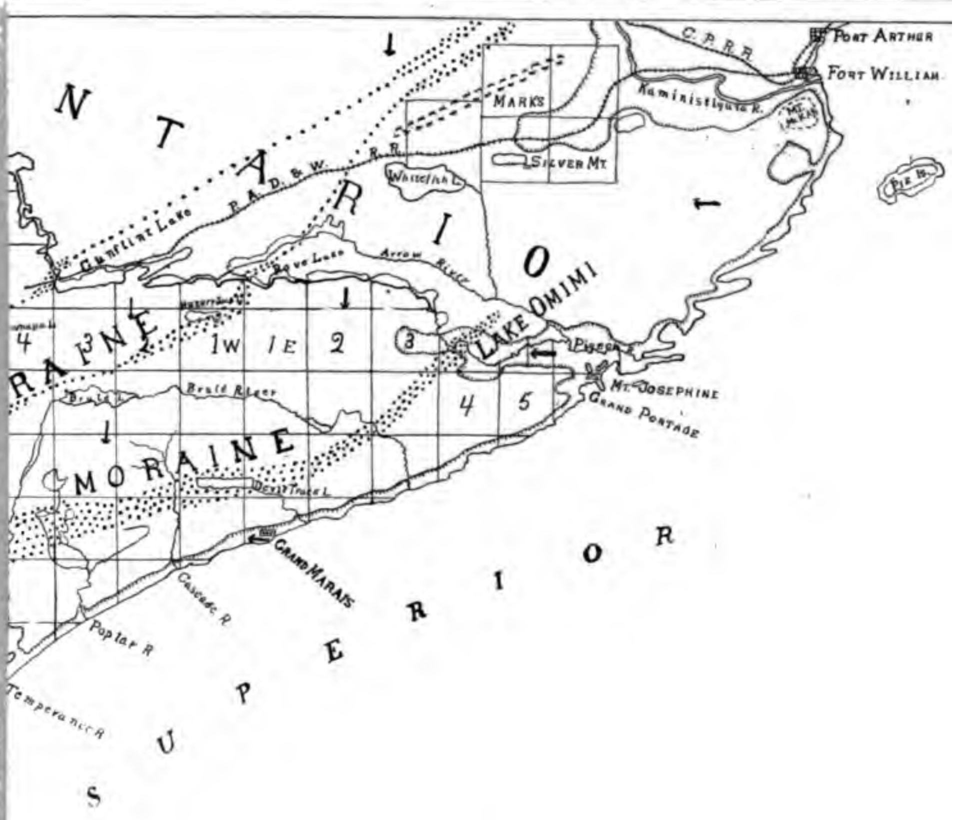
of the distribution of boulders. In view of these and other facts the moraines in north central Minnesota are "referred to two great lobes of the ancient ice sheet, a shorter one moving southwest through the lake Superior basin and a longer one moving around this from the northeast to the west and southwest. In their recession, these lobes formed successive slender and more or less curved reëntrant angles producing interlobate moraines, one arm of each being formed on the west side of the lake Superior lobe, and the other arm along the east side of the Red River lobe. The apex of this angle advanced toward the northeast until it grew into a slender moraine probably traceable along the Mesabi Range."

Professor Todd's objections against the previous arrangement of these moraines seem well founded. The lobate character of the ice sheet during its last stage of existence in northeastern Minnesota is evident.

The accompanying map (plate XI) showing the glacial geology of northeastern Minnesota is intended to emphasize the relation of the moraines. For the region west of Range 11, west of the 4th principal meridian the map and description accompanying it are taken from Mr. Upham's report already cited. For the region east of range 12, the descriptions are based almost entirely upon the writer's observations.

The morainic belts represented upon the map, approximately outline the very rough drift accumulations characterized by numerous kettle holes. Since the moraine immediately north of lake Superior does not appear to be a continuation of the original Leaf Hills moraine, although probably contemporaneous with it, the name Highland moraine will be used in order to prevent confusion until its western and southern connections have been determined. The correlation by Mr. Upham of the other moraines is satisfactory so far as the writer is able to determine.

Highland Moraine. This moraine is named from Highland station on the Duluth and Iron Range railroad, ten miles northwest of Two Harbors on lake Superior, and 1107 feet above the lake. The railway station, located in a deep recession in the south side of the moraine, is surrounded on all sides by high drift hills. The railroad crosses the summit of the moraine a mile north of the station at an altitude of



MAP
SHOWING THE GLACIAL GEOLOGY
OF
NORTHEASTERN MINNESOTA.
BY A. H. ELFTMAN.
1897.

Glacial striae.

Moraines.

Modified drift.

Glacial lakes.

30 MILES.

1744 feet above the sea and 1142 feet above lake Superior. This is the highest point reached on the railroad. The Highland moraine has its most prominent development in the vicinity of this station and can be most easily studied along a distance of fifteen miles by trails which start from Highland station.

The moraine is seen in several places along the Cloquet river and from Highland it extends continuously in a northeasterly direction to T. 59 N., R. 8 W., where it unites with the Itasca moraine. With an average width of two miles it runs nearly parallel with the shore of lake Superior at a distance of ten to fifteen miles north of it. Its maximum width is five miles.

Itasca Moraine. On the Duluth and Iron Range railroad this moraine occurs as a low belt of hilly drift from three to five miles northwest of the Saint Louis river. From the railroad the moraine continues in a northeasterly direction to the north of the source of the Saint Louis river in T. 59 N., R. 11 W. Its course then becomes somewhat variable but lies in a general easterly direction following approximately the town line between townships 59 and 60 north to its junction with the Highland moraine in T. 59 N., R. 8 W.

East of the union of these moraines a single prominent moraine continues in a northeasterly direction to the Pigeon river, diminishing in size toward the east until it disappears in the province of Ontario. This belt is well defined around lake Harriet,* T. 60 N., R 6 W.; around the lakes at the head of the Poplar river in T. 61 N., R. 3 W.; from the Cascade river in the southeastern part of T. 62 N., R. 2 W., to Devil Track lake, which lies in the midst of the moraine; in the southern part of T. 62 N., R. 1 E., and crossing the Pigeon river in sections 20 and 21, T. 64 N., R. 4 E. The moraine is characterized by a range of prominent hills 50 to 200 feet high extending its entire length.

Mesabi Moraine. West of range 11 west Mr. Upham describes this moraine as follows: "Along the Mesabi range east to the Embarras lakes northeast of Biwabik this moraine is merged with the Itasca moraine. At Mesaba station, on the

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*H. V. Winchell, 17th Ann. Report, Minn. Geol. and Nat. Hist. Survey, p. 102.

Duluth and Iron Range railroad, and within a mile southeastward, this Mesabi moraine comprises many hillocks and short ridges twenty to forty or fifty feet high. Thence continuing northeast, it is represented by characteristic knolly and hilly drift deposits and abundant bowlders on the south side of the western part of Birch lake in T. 61 N., R. 12 W."* Turning southward in the next five miles the moraine continues in a slightly north of east direction into the southern part of T. 61 N., R. 7 W., lying from two to five miles north of the Itasca moraine. For the next fifteen miles east of T. 61 N., R. 7 W., this moraine has never been definitely located. Eastward the moraine occurs in scattering morainic areas. These consist of the bowlder ridges and morainic deposits in the central part of T. 63 N., R. 4 W., and in the region north of Brulé lake, between this lake and Poplar lake. South and east of Hungry Jack lake T. 64 N., R. 1 W., along the Grand Marais and Rove lake road is a belt of moraine deposit several miles wide. This belt extends northward across the east end of Hungry Jack lake and across the international boundary near the west end of Rove lake. In Ontario this belt is represented by a prominent moraine west and north of the township of Marks.

Vermilion Moraine. This moraine, which was first described by Mr. Upham in 1893,† passes from the south shore of lake Vermilion northward to the region north of White Iron lake. Beyond this region the drift deposits are not thoroughly explored and on account of their scarcity it is difficult to map the course of this moraine. To the writer it seems that the drift deposits observed at the following localities determine its position: In the northeastern part of T. 63 N., R. 10 W,; the east central part of T. 63 N., R. 8 W.; Sec. 12, T. 64 N., R, 7 W.; Sec. 11, T. 64 N., R. 6 W.: several miles northwest of Little Saganaga lake; in the southern part of T. 65 N., R. 4 W.; on the international boundary several miles north of Gunflint lake; and northwest of the township of Marks.

The moraines whose courses are thus outlined and indicated on the accompanying map represent belts of drift quite

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*22nd Ann. Rep. Minn. Geol. Sur., p. 50.

†22nd Ann. Rep. Minn. Geol. Sur., p. 51.

distinct in character from that in other parts of this region. Each moraine as seen from a distance forms a range of irregular hills from fifty to two hundred feet above the surface in its immediate vicinity.

The Highland moraine, when viewed from the south, appears more abrupt, with a greater difference in elevation between it and the land southward than is seen from the north. With the other moraines the abruptness is seen on the north side. The moraine formed by the union of the Highland and Itasca moraine is abrupt on both sides.

Upon a closer examination it is found that in approaching the Highland moraine from the south, the land in general is devoid of any marked difference in elevation or roughness beyond that due to the position of the bedrock. The moraine is sharply defined and generally rises suddenly in hills one hundred and fifty feet high. The belt of irregular hills, in which occur numerous kettle holes over fifty feet deep, varies in width from one-half mile to five miles. Toward the north the hills are less prominent, rarely more than fifty feet higher than the land immediately beyond the moraine whose northern limit is thus not well defined.

The Itasca moraine west of range 12 west is not extensive but it increases in extent toward the east, forming a belt of hills from two to five miles wide, rising from twenty to seventy-five feet above the land to the south and twenty-five to two hundred feet above the land north of it. The northern boundary of the moraine is well defined while the southern boundary merges into the non-morainic drift.

East of T. 59 N., R. 8 W., the united Itasca and Highland moraines, hereafter designated the Itasca—Highland moraine, have their northern and southern boundaries sharply distinguished. This belt averages three miles wide in its entire extent and forms the highest land within the first fifteen to thirty miles north of lake Superior.

The Mesabi moraine is not extensive in its western confines. It reaches its maximum development in T. 60 N., R. 8, 9 and 10 W., and T. 61 N., R. 8 W. In these localities it varies from one-half a mile to four miles in width. Eastward the moraine is quite limited in extent until it reaches Hungry Jack lake where its hills are very conspicuous. Like the

Itasca moraine, the Mesabi moraine on its southern side merges into the flat drift. Its northern limit is well defined by irregular hills rising abruptly over two hundred feet above the average surface of the country. The northern edge of this moraine marks the dividing line in northeastern Minnesota between the heavily covered drift area to the south and that part where the drift is very scarce.

The Vermilion moraine which lies in the latter area was estimated by Mr. Upham* to have an average thickness of twenty-two feet in its greatest development. Northwest of the township of Marks this moraine is over a mile wide and 200 feet deep and possesses the same structure described in the other moraines.

Between the moraines the drift presents an even surface, occurring usually in low, rolling ridges, increasing in elevation as they approach the front of the moraines. These deposits consist partly of till and partly of modified drift.

THE NON-MORAINIC TILL.

Under this term is included the unstratified glacial drift which is found in the greater part of northeastern Minnesota and usually of no considerable thickness. On account of the heavily wooded condition of the region it is difficult in many cases to distinguish it from the modified drift. South of the Highland moraine the till is not more than twenty feet thick and usually only a few feet. In the greater part of this area it is covered by the lacustrine deposits of lake Duluth. In the triangle between the Highland and Itasca moraines the till appears in low rolling ridges with a general slope toward the west forming the valleys of the Saint Louis river and its eastern tributaries. A large part of this area is covered with the usual swamps and muskegs, so that over areas several townships in extent the surface varies only a few feet in altitude. The till in this area consists of alternating layers of material derived from the east and the northeast. This was described and illustrated by Upham.† It is also evident that in the region immediately north of the Highland moraine the upper till layer is of eastern origin, and that in the region im-

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*Op. cit. p. 52.

† Op. cit. pp. 43 and 44, and Plate II.

mediately south of the Itasca moraine the upper till layer is of northeastern origin. Between the Itasca and Mesabi moraines the till is largely covered by modified deposits and is usually not more than twenty feet thick. In T. 60 N., R. 9 W., however, it attains a thickness of more than fifty feet. North of the Mesabi moraine the till is scarce and when present is represented chiefly by boulders.

MODIFIED DRIFT.

The modified drift consists of the stratified gravel, sand and clay deposited by streams flowing from the retreating ice. Kames, eskers, plateaus, river deltas and valley drift represent it.

Kames are of common occurrence and are associated with all the moraines. They are especially well developed along the Highland and Itasca moraines and their eastern extension, the Itasca-Highland moraines. In the Mesabi moraine, between Hungry Jack lake and the international boundary, are also well formed kames, one of which is traversed for one-eighth of a mile by the portage from Rose to Rove lake. Both of the moraines northwest of Marks township in Ontario show a strong development of kames and kettle holes.

Eskers were observed only in a few places. The most prominent one is in T. 62 N., R. 1 W., one to two miles west of Devil Track lake. This is a narrow ridge over a mile long and fifty feet high, above the land on either side. It is composed of fine gravel and sand, with a few large boulders. In this vicinity are also numerous kames, which occur near the northern edge of the Itasca-Highland moraine.

Plateaus of sand and gravel similar to the kames in structure form isolated hills rising as high as 150 feet above the surrounding area. The most conspicuous plateaus occur immediately south of White Iron lake in T. 62 N., R. 12 W.; at the northeast end of Gabbro lake, T. 62 N., R. 10 W.: and at a number of localities several miles north of the Mesabi moraine. These plateaus are especially noticeable since they lie at some distance from the moraine.

River deltas occur most abundantly south of the Highland moraine. They were formed in connection with lake Duluth. The most prominent ones observed by the writer occur from

450 to 600 feet above the present lake Superior on the following rivers: Knife, Encampment, Gooseberry, Beaver, Baptism and Temperance rivers. Smaller deltas are found at still lower levels on these rivers as well as the Poplar, Cascade, Devil Track and Brulé rivers. In general it may be said that the first mentioned streams present favorable conditions for the formation of deltas at high levels and all streams at lower levels. The greater extent of the deltas at higher levels is due to the greater volume of water discharged through these rivers. In the area north of the Highland moraine the deltas are not as numerous nor as extensive. South of the Mesabi moraine in T. 60 N., R. 10 and 11 W., are several small deltas.

Valley drift consists chiefly of fine sand deposited in undulating and nearly level tracts between the moraines. These deposits are well shown in gravel pits and railroad cuts along the Duluth and Iron Range railroad. The best exposure is found at Cloquet River station, where an embankment twenty feet high and a fourth of a mile long shows numerous beds of stratified sand and gravel with very prominent cross bedding. The original deposit formed a nearly level plain about one-fourth of a square mile in area. In T. 60 N., R. 7 to 11 W., between the Itasca and Mesabi moraine the valley drift is extensively developed. So far as noticed these sand deposits usually occur above the till. In the region between the Itasca and the Highland moraines, where several overlapping till sheets exist, modified deposits are found under later till. This was noted by Spurr in T. 51 N., R. 17 W.*

WIND DEPOSITS.

West of the small lake in the N. W. ¼ of section 8, T. 60 N., R. 9 W., and in the east central part of T. 60 N., R. 10 W., are deposits of unstratified sand above the till and modified drift. These deposits present an uneven surface similar to that of the moraines. The material is composed entirely of fine sand. These dune like hills are referred to wind deposits which are derived from the extensive deposits of modified drift in the immediate vicinity.

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*22nd Ann. Report Geol. and Nat. Hist. Survey of Minn., p. 123.

DISTRIBUTION OF BOULDERS.

Boulders are very abundant in the drift of this region. Locally nine-tenths of the drift is made up of boulders from four inches to ten or fifteen feet in diameter. The boulders found in this region may be referred to two sources: 1st, the east; and, 2nd, the north and northeast. Those derived from the former source are composed entirely of rocks found near lake Superior, and consist of felsytes, quartz-porphyries, amygdaloidal diabases, Beaver Bay diabase, anorthosyte, and sandstones; those from the latter source consist of granites, schists, jasper, hematite, magnetite, slates and gabbros, rocks known to occur in place north of the present position of the boulders.

The areal limits of the boulders from these two sources are easily recognizable. The Highland moraine is composed entirely of material derived from the east. The Itasca moraine consists of northern drift. The Itasca-Highland moraine is composed of material derived both from the east and the north. The derivation of the drift included in this moraine, from two sources, was previously mentioned on the Poplar river* and around lake Harriet in T. 60 N., R. 6 W.† The Mesabi and Vermilion moraines are derived entirely from the north and northeast. In the triangle between the Highland and Itasca moraines the glacial drift is composed of alternating layers of northern and eastern drift.

While the northern limit of the southern and eastern drift is largely determined by the Itasca moraine, still the eastern drift has been observed at Biwabik and Birch lake on the Mesabi range; at lake Isabelle T. 62 N., R. 8 W. and on the Temperance river in T. 62 N., R. 4 W. The material at the last named places is scarce, and the fragments small in size, the largest being about two inches in diameter. As this drift occurs at a lower altitude and lies in the valleys of rivers whose sources are in the area covered by the eastern drift, some of it owes its present location to river transportation.

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*N. H. Winchell. Tenth Ann. Report Geol. and Nat. Hist. Sur. of Minn., 1881, p. 105.

†H. V. Winchell. Seventeenth Ann. Report Geol. and Nat. Hist. Sur. of Minn., 1888, p. 101.

The eastern drift has also been observed at considerable distances west of the area described in this paper.*

The greatest distance over which the boulders in this area have been transported extends one hundred and fifty miles. Numerous boulders of anorthosyte are found in the Highland moraine and to some distance north of it. They are also found in the St. Louis river valley, seventy-five miles west of Encampment island in lake Superior. The anorthosyte boulders just mentioned are to be referred to a strip not over six miles wide and forty-five miles long between Encampment island and Carlton peak on the north shore of lake Superior, the distinctive lithologic characters of which will be mentioned later.

The drift of the northern ice-lobe does not appear to have been transported a great distance. The greater number of boulders are from rocks whose ledges are not over fifty miles distant, and for the most part indeed are within twenty or thirty miles. It is also a conspicuous feature of this drift that in places the moraines are represented entirely by boulder ridges.

GLACIAL STRIÆ.

The direction and locality of the glacial striæ in northeastern Minnesota recorded up to 1893 have been tabulated by Mr. Upham.† Several important new observations are as follows:

On the rock which forms the outer part of Grand Marais harbor are numerous parallel glacial striæ and grooves from a few feet to fifty feet in length. There are two sets of these striæ which cross each other at a small angle. The more prominent and numerous striations run about west, the other set bears south of west. In a number of places west of Grand Marais are found striæ which run west, or a little south of west. South of the Pigeon river all striations run westerly.

The directions of the striæ in the region included in the accompanying map and indicated by arrows, may be briefly summarized as follows: South of the Highland and Itasca-

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*Geology of Minnesota, Final Report, vol. II, 1888. Various county reports.
Upham. 22nd Ann. Rpt., 1893, p. 44.
Spurr. 22nd Ann. Rept., 1893, p. 123.

†Op. cit., pp. 35-40.

Highland moraine the direction is about west, varying locally to 20° north of west; at Duluth the direction of the striæ varies, having a general southwest direction intersected by striæ running in all directions.

The glacial markings observed within ten to twenty miles north of the Itasca moraine run south to south twenty degrees west. The one exception at Allen Junction where the striations run south, forty degrees west, is attributable to the influence of the Giant's range five miles north of this locality. Northwestward of the above named limits the general direction becomes more westerly, becoming on Hunter's island S. 20° W., Rainy lake S. 40° W., and lake of the Woods S. 45° W. In many localities are numerous intersecting striations made during the last stages of the ice retreat.

GLACIAL LAKES AND RIVERS.

The water derived from the receding ice when hemmed in between the ice sheet on the one side and permanent land barriers on the others, formed lakes whose positions are marked at the present day by stratified clay, beaches and river deltas. The glacial lakes of the lake Superior region have been described with more or less detail during recent years.* The highest shore lines of the glacial lakes are approximately located upon the map.

Lake Saint Louis.† As the ice receded toward the east into the lake Superior basin the first lake formed was lake Saint Louis, southwest of Duluth. The outlet of this lake was toward the southwest from the central part of T. 47 N., R. 18 W., through a well defined river valley, at present seen along the Saint Paul and Duluth railroad between Barnum and Carlton. The highest point in this valley has an altitude of 1,125 feet above the sea. The ice barrier stood in the northwest part of T. 48 N., R. 16 W. Although the lake did not extend

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*Lawson 20th Ann. Rep. Geol. and Nat. Hist. Sur. of Minn., 1891, pp. 181-289.
Upham, 22d, ditto. 1893, pp. 54-64.
Taylor, AMER. GEOL. Vol. XIII, 1894, pp. 380-383; Vol. XV, 1895, pp. 119-120 and pp. 304-314.

†As recently described by Prof. N. H. Winchell in a paper as yet unpublished, read before the Minn. Acad. of Nat. Sciences Feb. 1897; also described in his unpublished report on Carlton county.

over forty square miles in area, it received a large volume of water from the Saint Louis river.

Lake Nemadji. When the ice had receded beyond the land barrier which formed the southeastern shore of lake Saint Louis, a lower outlet with an altitude of 1,070 feet above sea level, was uncovered in the northeast corner of T. 46 N., R. 18 W. This outlet crosses the northern part of the township and joins the outlet from lake Saint Louis in the northeast part of T. 46 N., R. 19 W. Beyond the last named locality the abandoned river channel continues to the southwest until it forms the valley of the Kettle river, which flows southward into the Saint Croix river. The stage of the glacial lake determined by the outlet just described is called lake Nemadji by Prof. Winchell, from the river Nemadji, which at present drains a large part of the region formerly occupied by this lake. Lake Nemadji continued to exist until a lower outlet by way of the Bois Brulé and Saint Croix rivers, thirty-five miles east of the western end was uncovered.

Lake Duluth. The present altitude of the Saint Croix outlet, according to Upham, is 1,070 feet above the sea level.* This is the same as the present altitude of the outlet of lake Nemadji. Allowing an uplift of former lake levels toward the northeast, the Saint Croix outlet when first uncovered was about ten feet lower than that of lake Nemadji.

Upham named the lake which had its outlet through the Saint Croix river, "Western Superior Glacial Lake."† Taylor used the name lake Duluth, without definition, upon a map recently issued.‡ The name lake Duluth is used in the present paper as a more appropriate and less cumbersome name for the lake whose outlet was by way of the Saint Croix river, and which was formed by an ice barrier extending during the maximum extent of the lake from the region a few miles east of Port Arthur to the next lower outlet near the eastern end of the lake Superior basin.

On account of the rapid rise of the surface of the land north of lake Superior the areal extent of this lake was not

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*Upham, Geol. of Minn. Final Report, Vol. II, pp. 642, 643. Mr. Upham has supposed that the original level was 80 feet higher, and that by erosion it acquired its permanent stage.

†22nd Ann. Report, Minn. Geol. & Nat. Hist. Survey, p. 54.

‡"Studies in Indiana Geography" 1897, Chapter X, p. 10.

much larger than that of the present lake. Lake Duluth occupied the greater part of region occupied by lake Nemadji. The prominent features of the lake are its clay deposits, beaches and deltas.

Clay Deposits. These deposits are abundant in the entire area of lake Duluth. In the region southwest of Duluth the clay does not occur at an altitude over 1,050 feet above the sea. Along the north shore of lake Superior the highest altitude of the clay rises toward the northeast. This has been verified by numerous aneroid measurements. North of Silver mountain, Ontario, the clay is found at an altitude of 1,200 feet above sea level.

The clay is stratified and varies in thickness from a few inches to one hundred feet, forming locally, flat areas of considerable extent. The most abundant deposits are found in the vicinity of the mouths of the larger glacial rivers. The clay is composed entirely of very fine grained particles. In the admirable sections through the clay along the Port Arthur, Duluth and Western railroad, from Port Arthur to Silver mountain, and in the region southwest of Duluth, it is seen that the clay originally had a blue or gray color. The weathered surfaces always show a yellow to red color, and a gradation from the blue to the red is noticeable in many recent exposures. The depth of alteration varies considerably, extending from five to twenty-five feet below the surface. Many streams have cut gorges through the deposit and have exposed the pre-lacustrine surface of glacial drift and the earlier rock formations.

Beaches. Above the clay, and often cutting into it, are beaches which represent the stationary periods of the lake. These beaches are found in numerous localities, but on account of the heavy timber it is impossible to follow them continuously. The highest beach of lake Duluth is always found above the clay, and generally represents the highest lacustrine deposit.

In the western end of the lake the altitudes of the glacial outlets and of the highest beaches, as they are at present recorded, do not agree, unless we suppose an ascent of the beaches of three to four feet per mile toward the northeast. This does not seem warranted by observations in other parts

of the region. It seems that a further investigation in the field is necessary to determine whether the highest beach at Duluth, 1,137 feet above sea level, is associated with the glacial passes thus far described, and whether the Boulevard beach at Duluth may not be regarded as the highest beach of lake Duluth.

Along the Duluth and Iron Range railroad the highest margin of the lake is found between five and six miles north of Two Harbors, and at an altitude of about 1,100 feet above sea level. The lake shore is not clearly defined on account of the even slope of the glacial drift, but it does not appear to extend over 500 feet above lake Superior. At mount Josephine the highest beach has an altitude of 1,209 feet above sea level. North of Silver mountain the Port Arthur, Duluth and Western railroad crosses the highest beach, about thirty-eight and one-half miles west of Port Arthur, at an altitude of about 1,230 feet above sea level.

Deltas. Delta deposits are prominently developed on the Knife, Encampment, Gooseberry, Beaver, Baptism and Temperance rivers. The most extensive development of these deltas was contemporaneous with the stages of lake Duluth.

Lake Omimi. Before the ice had receded beyond mount Josephine it retained a lake of about 40 square miles in area lying in the upper valley of the present Pigeon river. The lake bed has an altitude of 1,255 to 1,360 feet above the sea. Its lowest point is thus about 50 feet higher than the upper stage of lake Duluth. The chief deposit consists of stratified clay, exposed along the Pigeon river and its tributaries. Beaches have as yet not been identified. The western shores of this lake were formed by high rock ridges. The ice barrier during the largest extent of the lake stood in the vicinity of the western end of the Grand Portage trail. The outlet, which has not been definitely located, was most probably toward the southeast, and closely connected with the ice barrier, which, upon receding, continually uncovered lower ground. This lake in part occupied a portion of the area previously occupied by the northern ice lobe. When the ice receded from the vicinity of Grand Portage, lake Omimi disappeared. The name Omimi is taken from the Chippewa name for Pigeon river.

Lake Kaministiquia. This lake was described by Taylor* after this paper was written. As the writer has since then visited that region, his interpretation of the facts is added. As it has been mentioned before the highest lacustrine deposits along the Port Arthur, Duluth and Western railroad occur in the vicinity of Silver mountain and do not extend above the altitude of 1,230 feet above sea level. The region northwest of Silver mountain is very favorable to the deposition of lake beaches, etc., had it been submerged. On the north side of the Giant's range, which crosses the central part of Marks township from the southwest, lacustrine deposits occur at an altitude of 1,500 feet and less, or about 300 feet higher than those at Silver mountain. These higher deposits correspond to those described by Taylor along the Canadian Pacific railroad. It seems that the area of lake Kaministiquia is more restricted than that originally outlined. Lake Kaministiquia is regarded by the writer as a lake occupying the basin formed on the south by the Giant's range, on the west and north by the "height of land," and on the east by the ice sheet. The southwestern point of the ice barrier at the time of greatest extent of the lake stood at the east end of the Giant's range, near the Kaministiquia river. Upon the recession of the ice beyond the high land, the lake immediately emptied into lake Duluth. It is noticeable that the lake existed in a region occupied at an earlier date by the northern ice lobe.

Lake Algonquin. The non-existence of lake Warren in the lake Superior region has been quite fully discussed by Taylor† and Upham.‡ The beaches below those of lake Duluth are referred to the stages lake Algonquin. These beaches are without strongly marked or uniform characters which would serve to identify them without continuous tracing. On this account little can be added to the previous knowledge of this lake in the region northwest of lake Superior. East of Port Arthur the highest beach recorded by

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*AMER. GEOL., Vol. XX, pp. 117.

†AMER. GEOL., Vol. XVII, 1896, pp. 253-257; pp. 397-400; Vol. XVIII, 1896, pp. 108-120; "Studies in Indiana Geography," Chap. X, 1897.

‡AMER. GEOL., Vol. XVII, 1896, pp. 238-240; pp. 400-402; Vol. XVIII, 1896, pp. 169-177.

Taylor and others seems to be the highest beach of lake Algonquin.

Nipissing Great Lakes. The highest beach of this post-glacial lake, called the Nipissing beach by Taylor, forms a conspicuous feature near the level of lake Superior from Beaver Bay to Port Arthur. The conclusions drawn by Taylor with respect to this beach are satisfactory. The beach is 61 feet above lake Superior at Port Arthur and is readily recognized at lower levels, at Wauswaugoning Bay, Grand Portage, Grand Marais, Cascade river, three miles east of the Temperance river at Tofte postoffice, and one-half a mile west of the Baptism river. West of the last-named locality the beach has been obliterated by recent wave action, and probably passes below the level of lake Superior near Beaver Bay. Taylor places its distance below the lake at Duluth at 25 feet. This gives a rise of 86 feet toward the northeast, between Duluth and Port Arthur.

Lake Gabbro. North of the Mesabi moraine and east of Gabbro lake, a glacial lake having an area of one hundred square miles at its maximum extent, existed for some time after the recession of the ice from the moraine. The shores of the lake were formed by the Mesabi moraine on the south, a high rock ridge on the west, the ice barrier on the north and the highlands on the southeast. This region forms a basin, sloping toward the northwest, which is covered more or less with stratified sand and fine clay. Beaches have not been identified. The short duration of the lake and the character of the region in which it existed did not present favorable conditions for the formation of prominent beaches. The outlet was south to the Stony river. The lake was named lake Gabbro on account of its central location in the gabbro area of northeastern Minnesota.

Glacial Rivers. The courses of the glacial water are quite conspicuous in many places. The valleys of the Cloquet, Saint Louis and Embarras rivers show that these rivers at one time were much larger. The extensive stratified deposits in these valleys indicate a drainage from the northeast. At the headwaters of these rivers abandoned channels across the present water divide show that their sources were further north and east. The channel across the central part of T. 59

N., R. 11 W., connects the Saint Louis with the Stony river. The southern head of the Stony and that of the Cloquet river are on the same level. The sources of the Baptism and Isabella rivers are upon the same level in a valley which cuts through the Itasca-Highland moraine. The stratified deposits in this valley south of the moraine are composed partly of material brought from the region north of the moraine, indicating a drainage toward the south. These are the chief glacial rivers, others of minor importance show the same phenomena as those just mentioned.

GLACIAL EROSION.

Glacial erosion in the greater part of this region did not extend much beyond the removal of the decomposed surface rock. It was most active along the main direction of the ice lobes. The change in the topography is not very marked. The tendency to change the V-shaped valleys of the preglacial erosion to U-shaped valleys is well exhibited along the north shore of lake Superior where the low dipping strata are cut off near the side of the valley. The Sawteeth mountains, which are chiefly due to pre-glacial faulting, were not changed to any extent beyond the rounding off of the edges and sides facing the direction from which the ice came. The greater part of the rock which makes up these hills is a medium grained compact diabase, which resists weathering better than the amygdaloidal rocks above it, which have been largely removed by glacial action.

The rocks forming the present surface are generally quite fresh. Yet in some areas the basal gabbro is entirely decomposed and does not appear to have been subjected to extensive erosion. The existence of these areas may be due to deep local pre-glacial weathering. When the region was levelled off by glaciation the lower portion of the altered rock remained in place.

SUMMARY.

The evidence presented by the structure and composition of the glacial drift, the striæ, and other glacial phenomena, show that the drift deposits were formed by two lobes, one of which moved in a general southwesterly direction through

the lake Superior basin, and the other with its central axis across the Rainy lake region, moved S 40° W.

The Superior lobe overflowed its basin and spread westward and northward to the Giant's range. The ice then receded from the north at least as far as Highland, but again advanced northward as far as Giant's range. Receding again to Highland another advance was made, extending northward from five to ten miles. After the recession from the last advance, the Highland moraine was formed along the rim of the basin. Further east, in conjunction with the Rainy lobe, it formed the Itasca-Highland moraine. During the farther recession of this lobe the glacial lakes Nemadji, Duluth, Omimi and Kaministiquia were successively formed and drained.

The history of the Rainy lobe is more complex than that of the Superior lobe. While the latter filled its basin, the former filled its basin, the southern barrier of which was the Giant's range. The till between the Highland and Itasca moraine shows that each ice lobe alternately advanced beyond its basin and retreated. At least two such excursions by each lobe are recorded in cuts along the Duluth and Iron Range railroad. The Rainy lobe, during the recession, subsequent to the return from its last southern trip formed the Itasca, Itasca-Highland, Mesabi and Vermilion moraines. The two lobes were contemporary, forming the Highland, Itasca and Itasca-Highland moraines at the same time. While these moraines were being formed the glacial water was carried off by the Saint Louis and Cloquet rivers. The Superior lobe then receded toward the northeast and its northern border remained in close proximity to the Itasca-Highland moraine.

The Rainy lobe receded northward from the Itasca and Itasca-Highland moraines. Since lake Omimi covered in part the region occupied by this lobe, the Superior lobe had not receded beyond mount Josephine at the time the Mesabi moraine was being formed. The drainage of the Rainy lobe was to the southward, chiefly through the Saint Louis, Cloquet, Isabelle-Baptism, Temperance and Pigeon rivers. The large volume of water discharged into lake Duluth carried with it an abundance of drift. The coarser material was deposited at the mouths of the rivers, forming deltas, and finer

material was carried into the lake forming the extensive clay deposits. When these waters found an outlet toward the north, the volume emptying into lake Duluth was greatly reduced and the transportation of debris correspondingly diminished.

The scarcity of the drift north of the Mesabi moraine shows that the ice did not linger long in that region. From the position of the moraines it seems that the recession in the western part of the region was even more rapid than that in its eastern portion. This would indicate that the general recession of the Rainy lobe was toward the northeast. The drainage, while the Vermilion moraine was being formed, was chiefly from the northeast through valleys at present occupied by the streams emptying into Birch lake, and from thence westward through the Embarras river to the Saint Louis river. After its brief rest at the Vermilion moraine the ice receded to the northeast into Canada. Since lake Kaministiquia occupied in part the region covered by the Rainy lobe after this lobe had receded beyond the Vermilion moraine, the Superior lobe had not, at that time, receded beyond Port Arthur.

It may be mentioned in passing that this interpretation of the moraines may necessitate a revision of the interpretation of the glacial phenomena in central Minnesota. So far as the writer can judge from his observations and the descriptions* of the glacial drift in this part of the state it seems that there is evidence of the meeting of ice lobes from different directions; i. e., the Superior lobe from the northeast and another lobe from the northwest. The relation of these lobes seems to be analogous to that just described between the Superior and Rainy lobes. It may be suggested here that the Kettle moraine of the Wisconsin geologists, which is recognized over an extensive territory, and whose relative chronological position has been determined, continues into Minnesota, and perhaps is represented by the Highland, Itasca and Leaf Hills moraines.

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*Final Report, Vol. II, Minn. Geol. & Nat. Hist. Survey, 1888, County Reports.

AN ACCOUNT OF THE RESEARCHES RELATING TO THE GREAT LAKES*.

By J. W. Spencer, Toronto.

An old text book upon geology briefly says that the lake basins are due to movements of the earth's crust. What the movements were and how they affected the history of the great lakes was left a subject of discovery for recent years. In the mean while, theories arose as to their origin, the disposal or modification of which was fraught with difficulties as great as those of discovering the history itself. Ramsay had attributed the origin of the American lakes to glacial excavation;† Hunt, Newberry, Carll and many others had collected the evidence of buried channels occurring in the lake region. Gen. G. K. Warren‡ had followed up the observations of Prof. H. Y. Hind § in the history of the Winnipeg basin, and proposed the northeast warping as closing the Ontario basin, to such a degree that he may be considered the father of lacustrine geology. But the great impetus towards the investigation of the great lakes is due to Prof. J. S. Newberry, whose contribution was followed by one from Prof. E. W. Claypole.¶‖ To give a full account of the researches concerning the great lakes, and to tell how each author had contributed to the subject would make a very long chapter. As the present writer has been so closely connected with the pioneering study of the subject, and has announced progress from time to time before the American Association it seems a fitting opportunity to tell how his investigations have been influenced by his co-workers, leaving to others the narration of the most recent studies.

Newberry followed upon the lines of Ramsay in attributing the basins of the lakes to glacial excavations, yet there was a counter current in his writings which finally advocated that the glacial excavation had taken place only after their courses

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*Read at the Detroit meeting of the A. A. A. S., 1897.

†Quart. Jour. Geol. Soc., Lond., vol. XVIII, pp. 185-204. 1862.

‡Appendix J., Rep. of the Chief of Engineers, U. S. A., 1875; Am. Jour. Sci. (3), vol. XVI, 1878, pp. 416-431.

§Report on the Assiniboine and Saskatchewan Exploring Expedition. By Henry Youle Hind. Toronto, 1859, pp. 1-20.

‖Geology of Ohio, vol. II, 1874, pp. 72-80.

¶On the pre-Glacial Geography of the region of the Great Lakes. E. W. Claypole. Can. Nat., vol. VIII, 1877, pp. 187-206

had been pre-determined by river action. Adopting the teachings of Agassiz and Newberry, and going much farther, an influential school was developed which attributed the superficial features of the northern regions almost entirely to the action of continental ice,—in spite of the teachings of Lesley, Dawson, Whitney and others. The extreme views, as represented by Dr. G. J. Hinde,* made the ice plough dig out the St. David's, Dundas, and other valleys, irrespective of their direction, as compared with that of the ice flow. Such speculations were most common at the close of the eighth decade of the century, when the writer commenced his studies upon lacustrine history—concerning which his first paper was on the "Discovery of the Outlet of the Basin of Lake Erie, etc.,† (1881). The appearance of this "avant courier," was due to the enthusiastic reception given by Prof. J. P. Lesley to the writer's discovery of the reduction of rocky barriers beneath the superficial drift, between lake Erie and the Dundas valley, at the head of lake Ontario, indicating an outlet for the Erie basin by a channel, the lower end of which is deeply buried by drift deposits. Prof. Lesley pointed out that this discovery satisfied the necessity for some such outlet to the Erie basin, as Hunt and Newberry had found buried channels beneath the lake, and Mr. J. F. Carll had discovered that the drainage of the Upper Allegheny, and other streams, had been reversed, having flowed northward into the Erie basin in pre-glacial days.

The writer's paper referred to not only described the outlet of the Erie basin, but also showed that the Niagara river was not needed in ancient times. Shortly afterwards this idea was confirmed by Dr. Julius Pohlman ‡ who found that the Niagara channel was not sufficiently deep for the drainage of the buried valleys in the vicinity of Buffalo.

In the same paper, the valley-like features beneath the lake waters were analysed and established. But at that time

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*Glacial and Interglacial strata of Scarboro Heights, etc. Canadian Journal, April, 1877, p. 24.

† Discovery of the Preglacial Outlet of the Basin of Lake Erie into that of Lake Ontario; with notes on the Origin of our Lower Great Lakes. By J. W. Spencer; Proc. Amer. Phil. Soc., XIX, 198, 2n., March 30, 1881, pp. 300-337.

‡ The Life-history of Niagara. By Julius Pohlman. Trans. Am. Inst. Min. Eng.

the course of the ancient drainage could not be traced beyond the meridian of Oswego. The writer also objected to the theory of the glacial excavation of the basins on account of the stream-like sculpturing of the land, and the sub-lacustrine escarpments; and on account of the glaciation of the region being everywhere at sharp angles to the escarpments, whether above or below the surface of the lakes. These views and the discovery of the outlet for the ancient Erie basin confirmed the teachings of Prof. J. P. Lesley, who, from being a progenitor of the science of topography became the father of geomorphy, of which the lake history is one of the phases. In speaking of the origin of the lake valleys, Prof. Lesley* says: "For a number of years, I have been urging upon geologists, especially those addicted to the glacial hypothesis of erosion, the strict analogy existing between the submerged valleys of lakes Michigan, Huron and Erie, and the whole series of dry Appalachian 'valleys of VIII', stretching from the Hudson river to Alabama; also of Green bay, lake Ontario and lake Champlain, with all the 'valleys of II. and III.' One single law of topography governs the erosion of them all, without exception, whether at present traversed by small streams or great rivers, or occupied by sheets of water; the only agency or method of erosion common to them all being that of rainwater; not in the form of a great river, because many of them neither are nor ever have been great waterways."

Notwithstanding the short-comings, and what are now known to be errors of detail, the paper on the pre-glacial outlet of Erie attracted considerable attention as a new departure; and at the time Prof. James Geikie, who is well known to be one of the leading glacialists, expressed himself as follows, under date June 21, 1881: "I have always had misgivings as to glacial erosion of the great lakes, * * * and now your most interesting paper comes to throw additional doubt upon the theory in question. Possibly those who have upheld that view will now give in. Your facts seem, to me at least, very convincing. I never could understand how those great lakes of yours could have been ground out by ice. The

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*Report Q4 of the Geological Survey of Pennsylvania, 1881. pp 399-406.

physical conditions of the ground seem to me very unfavorable." Prof. G. K. Gilbert, on June 15, 1881, wrote: "My first geological field work was in the drift of the Erie basin, and the problem of the origin of the basins of the great lakes has always had great attraction for me. Had I been able to understand its solution, my working hypothesis would have been that which you have demonstrated so thoroughly. * * * The matter has certainly never received a demonstration until your paper appeared. * * *"

At this time the writer was struggling to find the outlet of the basins, and looked in every possible direction for buried channels without avail. While the St. Lawrence valley, beyond the outlet of lake Ontario, was evidently only a continuation of the drowned valley occupied by the lake, and while the lower St. Lawrence indicated an elevation of the continental region to more than 1,200 feet (when the cañon of the Saguenay was being excavated), the evidence of the local oscillation of the earth's crust was not yet forthcoming. The deep cañon of the Dundas valley, and the observations of Prof. Gilbert that the Irondequoit bay was drowned to a depth of 70 feet was taken as evidence of terrestrial oscillation, but later the writer found that the St. Lawrence, after leaving Ontario, was in part flowing over a valley buried or drowned to a depth of 240 feet; accordingly the Dundas and Irondequoit valleys were no evidence of local oscillation, which had to be found elsewhere.

In concluding a notice of this early work,* the modern aspect of the Niagara river was emphasized, and the valley of St. Davids was regarded as of inter-glacial origin—in deference to the prevailing theories of the time—in place of being, as is now known, the channel of an insignificant stream of greater antiquity. The Finger lakes of New York were explained as closed up valleys which had formerly drained the rivers of the highlands of New York, as for example Seneca lake, which has since been found to be the ancient course of Chemung and its tributaries. About this time the writer, from the data collected by the Geological Survey of Pennsyl-

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*A short study of the Features of the Great Lakes, etc. J. W. Spencer. Proc. A. A. A. S., vol. XXX, 1881, pp. 131-146; and Surface Geology of the Region about the western end of lake Ontario. J. W. Spencer, Can. Nat., vol. X, 1882, pp. 213-236, and 265-312.

vania, pointed out the probability that the Monongahela and upper Ohio had formerly been reversed and drained into the Erie valley.* This hypothesis was afterward amplified by Dr. P. Max Foshay,† disputed by Prof. I. C. White; modified and confirmed by Mr. F. Leverett,‡ and finally, with some modifications, reconfirmed by Prof. I. C. White.§ In order to test the validity of his objections to the hypothesis of glacial excavation, the writer visited Switzerland and Norway for the purpose of personally observing the mechanical effects of modern glaciers, with the result that he saw in them only the agents of abrasion—the ice moulding itself round obstructions, or smoothing off irregularities, and not ploughing out channels.‖ Indeed, in a more recent visit to Norway, it became apparent that the great glacial valleys still preserve many base levels of erosion—the doctrine of which has not been applied to them, and consequently their history is as yet unwritten. The extreme views concerning glacial erosion, held a decade ago, are now greatly modified and do not belong to the present day.

In 1882, fragments of great beaches, and others which were delta deposits, were described as occurring about the western end of lake Ontario at various elevations from 500 feet above the lake down to its present level.¶ Other fragments of beaches had been known for many decades, the most notable of which were the ridge roads of New York state, that Prof. James Hall, as early as 1842, found to be rising gently upon proceeding eastward;** and the same was found to be true at the eastern end of lake Ontario. About this time Prof. Gilbert was studying the beaches of the western lakes, and Mr. Warren Upham those of the Winnipeg basin. The

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*On the ancient upper course of the Ohio river emptying into lake Erie. Proc. Am. Phil. Soc., Phil., vol. XIX, 1881.

†Preglacial Drainage and recent Geological History of western Pennsylvania. Am. Jour. Sci., vol. XL, 1890, pp. 397-403.

‡Pleistocene fluvial plains of western Pennsylvania. Am. Jour. Sci., vol. XLII, 1891, pp. 200-212; and Further studies of the Upper Ohio basin. Am. Jour. Sci., vol. XLVII, 1894, pp. 247-283.

§ American Geologist, vol. XVIII, 1896, pp. 368-379.

‖ The erosive power of glaciers as seen in Norway. Geol. Mag., Lond., Dec. iii, vol. IV, 1887, pp. 167-173.

¶ Surface Geology about the region of the western end of lake Ontario, cited before.

** Geology of New York. Vol. IV, 1843, p. 351.

beaches in both places were found to record the evidences of gentle terrestrial movements. Following up his investigations, Prof. Gilbert connected the various fragments of a great beach upon the southern and eastern sides of lake Ontario, as far as Adams Centre, near Watertown, N. Y.,* and found that the old waterline was deformed to the extent of several hundred feet in proceeding northeastward. This was an admirable piece of work, which was invaluable to the writer, who extended the observations farther† and made use of them in measuring the amount of the long sought for terrestrial deformation at the outlet of lake Ontario, and found that these post-glacial movements were sufficient to account for the rocky barrier across the Laurentian valley, producing the basin which retains the waters of lake Ontario. The channels across this rocky barrier, however, were closed with drift deposits reaching to a depth of 240 feet. In thus establishing the ancient drainage of the Ontario basin, after years of observation, often representing but little progress, the phenomena of the basin were discovered without the glacial theory of erosion. Then the writer found that the drowned channels cross lake Huron, and passing through Georgian bay, continued beneath hundreds of feet of drift, eastward of the Niagara escarpment, and joined the Ontario valley a few miles east of Toronto. A similar channel (the Huronian) crossed the state of Michigan, passed through Saginaw bay, and over the sub-lacustrine escarpment, to the deeper channel of the Huron basin.‡ The Erie (Erigan river) drainage had been found to pass into the head of the Ontario basin. Thus was discovered the course of the ancient Laurentian river and its tributaries of antiquity. These upper basins were also affected by the terrestrial tilting recorded in the beaches, as well as by the drift obstructing them.

Prof. Gilbert, who had, many years before, mapped beaches at the head of lake Erie§ afterwards measured the

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*Report of the meeting of the Am. Assc. Adv. Sci., Science, Sept., 1885, p. 222.

†The Iroquois Beach: a Chapter in the Geological History of Lake Ontario, by J. W. Spencer. Trans. Roy. Soc. Can., 1889, pp. 121-134. (First read before Phil. Soc., Wash., March, 1888.)

‡Origin of the Basins of the Great Lakes. Q. J. G. S. (Lon.), vol. XLVI, 1890, pp. 523-533.

§See Geology of Ohio, vol. II, 1874.

deformation recorded in the deserted shore at the eastern end of the lake;* while the writer surveyed the old water margins across Michigan, and on the Canadian sides of lakes Ontario, Erie and Huron, and in portions of New York.† After this, very little work was done upon the deserted shores for several years, when Mr. F. B. Taylor commenced his researches about the northeast portion of Georgian bay, lake Michigan, etc.;‡ and Dr. A. C. Lawson carried on similar observations north of lake Superior,§ and Prof. H. L. Fairchild in New York. The deserted beaches show but little terrestrial oscillation about the western end of lake Erie, but it increases towards the northeast and amounts to four to seven feet per mile.

With the surveys of the deserted beaches, new questions arose concerning the history of the lakes and of Niagara river, which forms an inseparable chapter. At the same time, opposing hypotheses presented themselves.

None of the beaches have been fully surveyed. They occur at various altitudes from near the greatest elevation of the land down to the levels of the lakes, and they have not always been separated from other Pleistocene deposits. While there are questions as to the higher forms, those from lower levels have undoubtedly been accumulated about extensive bodies of water—the character of which is the subject of disagreement. The writer has regarded them as accumulations at sea-level, and other observers as margins of glacial lakes, irrespective of their elevation. The theoretical aspect is not one likely to be settled speedily. Those who advocate the glacial character of the lakes have sought to terminate the beaches against morainic deposits to the northeast, but their

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*The History of the Niagara River. 6th Rept. Com. State Res. Niag., Albany, 1890, pp. 61-84.

†The Iroquois Beach, etc., cited before. Deformation of the Iroquois Beach and Birth of Lake Ontario, Am. Jour. Sci., vol. XL, 1890, pp. 443-451; Deformation of the Algonquin Beach and Birth of Lake Huron. Ib., vol. XLI, 1891, pp. 11-21; High Level Shores in the Region of the Great Lakes, and their Deformation, Ib., vol. XLI, 1891, pp. 201-211; Deformation of Lundy Beach and Birth of Lake Erie, Ib., vol. XLVIII, 1894, pp. 207-212.

‡Numerous papers recently published in Am. Jour. Sci., American Geologist, and Bul. Geol. Soc. Am.

§Sketch of the Coastal Topography of the North Side of Lake Superior. 20th Report of the Geol. Sur. Minnesota, for 1891, pp. 181-289.

ice dams have been frequently thrown along lines beyond which the beaches have subsequently been traced. Thus Prof. Claypole[*] made ice dams in Ontario where open water, bounded by beaches, was afterwards found to prevail. At Adams Centre, Prof. Gilbert drew an ice dam for the Ontario basin, beyond which, however, the writer found that the old shore line extended, and this was later confirmed by Prof. Gilbert. Mr. Leverett made an ice dam at Cleveland, beyond which the writer has been informed by two observers that the beach extends, and Prof. Gilbert and Mr. Leverett described another glacial dam near Crittenden, N. Y., beyond which the beaches have been discovered by Prof. Fairchild. Another diagnosis of the glacial lakes is the occurrence of gravel floors over low divides, which are regarded as the outlets of them, and upon this feature alone many such lakes have been named. But the advocates of these glacial outlets have not explained how the terraces (at hundreds of feet above the drainage) upon the southern side of them are indistinguishable in character from those upon the northern side.[†] If these supposed outlets be evidence per se of glacial dams then the most perfect which the writer has ever seen may be found within 16° of the equator, at an altitude of less than 800 feet, suggesting that the Mexican gulf had a glacial dam, discharging into the Pacific ocean across the isthmus of Tehuantepec—a suggestion which no one would seriously consider. The writer has also presented the hydrostatic objections[‡] to the impossible long continuance of some of the supposed dams, the location of which demands their drainage across ice itself, which would soon be penetrated by the warmer waters so as to reduce their level. By straightening out the deformation recorded in the deserted shore-lines, some of the beaches are shown to have undoubtedly been formed at sea-level.[§] While recent surveys report the discovery of additional glacial lakes, or the splitting up of those

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[*] Report of the meeting Am. Assoc. Adv. Sci. Science, Sept., 1895, p. 222.

[†] Channels over divides not evidence per se of glacial dams. J. W. Spencer. Bull. Geol. Soc. Am., vol. III, 1891, p. 491.

[‡] Post-Pliocene continental subsidence versus ice-dams, by J. W. Spencer. Bull. Geol. Soc. Am., vol. II, pp. 465-476, 1890.

[§] The Iroquois Beach, etc., cited before; and, Deformation of the Iroquois Beach, cited elsewhere.

first described under new names, the survey of the high level terraces in the mountain regions has suggested to the writer counterbalancing evidence of the occurrence of glacial dams, but this is a study which has been postponed, partly on account of the prejudice against post-glacial subsidence and partly on account of the writer's absorption in other questions of physical changes. Whatever may be the ultimate fate of the theory of glacial dams, the opposing hypotheses have given zest to the investigations to the degree of advancing our knowledge of the lake history.

In the survey of the beaches, besides the terrestrial deformation recorded, there seems to be no more important discovery than when the writer found how the Huron, Michigan and Superior waters (the Algonquin gulf or lake) originally emptied to the northeastward of the Huron basin in place of discharging into lake Erie; after which by the northeastern tilting of the land "the waters were backed southward and overflowed into the Erie basin, thus making the Erie outlet of the upper lakes to be of recent date."* This conclusion was established by the survey of the Algonquin beach which recorded the necessary tilting. The first survey was suspended near Balsam lake, where an overflow was found; and, accordingly, in the original announcement, the generalizations were not carried farther, although there was a lower depression in the vicinity of lake Nipissing, which was shortly afterwards made use of by Prof. Gilbert† and the writer. With the further elevation of the land, the lower beaches—partly measured at that time (1887-8), represented the surface of the Algonquin water discharging by the Nipissing route alone.‡ This has since been worked out by Mr. Taylor.§

Co-existing with the Algonquin gulf or lake was the Lundy gulf or lake, occupying part of the Erie basin, and extending into the Ontario, having substantially the same level. Both of these bodies of water extended much farther towards the northeast than their successors, although more contracted in the opposite directions—the effect of the more recent tilt-

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*Proc. A. A. A. S., vol. XXXVII, 1888, p. 199.

†The History of the Nipissing River.

‡Deformation of the Algonquin Beach, cited before.

§The Ancient Strait of Nipissing. F. B. Taylor. Bull. Geol. Soc. Am., vol V, 1893.

ing of the land. Prior to the existence of these separate bodies of water, higher shore-lines were formed, and the great gulf or lake bounded by them was called the Warren water, which name the writer has defined as applicable to the great open water of the region, until after the formation of the Forest beach—its most perfect episode—after which it was dismembered into the Algonquin and Lundy waters.*

During the changing stages of Warren water, its configuration was somewhat varied but not sufficiently to call the water by a multiplicity of names, according to the changing levels. The old shore lines form prominent features, requiring nomenclature for the most important. And additional naming only adds confusion. Some of the beaches have been renamed by Mr. Leverett,† contrary to the usage of naturalists.

With the continued elevation of the land, the Algonquin water sunk to the level of the Nipissing beach (of Taylor) and the Lundy became dismembered, and formed an insignificant lake Erie.‡ In the Ontario basin, the water sunk to the Iroquois beach and lower levels, and Niagara falls had their birth, after the river had first been a strait. Remnants of beaches of that time were long ago observed, not only in the vicinity of Niagara, but also at the head of the lake. With the temporary pauses recorded, the waters of the upper level were speedily lowered to that of the Iroquois beach, and then the Niagara river descended only 200 feet, in place of 326 feet, as at present. The effect of this diminished descent upon the excavating power of the falls was first pointed out by the writer in 1888§ and published in 1889. With the continued lowering of the waters in Ontario basin, the descent of the Niagara increased to 80 feet more than at present, as first shown by Prof. Gilbert; but later, by the tilting of the earth's crust north of the Adirondack mountains, the outlet of the Ontario basin was raised, causing the backing of the waters, so as to reduce the descent of Niagara river to its present amount.

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*High-level shores in the region of the Great Lakes, etc., cited before.

†On the correlation of the New York moraines with the raised beaches of lake Erie, by Frank Leverett. Am. Jour. Sci., vol. L, 1895, pp. 1-20.

‡Proc. A. A. A. S., 1888, p. 199.

§The Iroquois Beach, etc. Trans. Roy. Soc. Can., 1889, p. 132.

In 1886, after the third survey of Niagara falls (by Prof. Woodward), the rate of recession was found to be much greater than had formerly been supposed. Prof. Gilbert then made a short study of the falls, the conclusions concerning which are summed up as follows by that author:* "The problem admits of expression in an equation:

$$\text{Age of gorge equals} - \frac{\text{Length of gorge.}}{\text{Rate of recession of falls.}}$$

- Effect of antecedent drainage.
- " " thinner limestone.
- " " thicker shales.
- " " higher fall.
- " " more floating ice.
± " " variation of detrital load.
± " " chemical changes.
± " " changes of river volume.

"The catchment basin was formerly extended by including part of the area of the ice sheet; it may have been abridged by the partial diversion of Laurentian drainage to other courses." He had divided the length of the gorge by the maximum rate of recession, finding the product to be 7,000 years. If the equation be carefully examined, together with the cited quotation, all the important changing effects in the physics of the river would lessen the estimated age of the cataract below 7,000 years, except the effect "by partial diversion of the Laurentian drainage to other courses," of which no evidence was suggested; nor was any lengthening of time shown as necessary, by the long inferior hight of the falls. Henceforth, Prof. Gilbert was naturally quoted as an authority that the age of the falls was only 7,000 years. This conclusion did not satisfy the writer, who from the evidence of the beaches, especially the Iroquois,† found that the rate of recession must have been for long ages much less than now, on account of the inferior hight of the falls; and also on account of the greatly diminished volume of water, owing to the overflow of the upper lakes to the northeast, until in recent days. But how much of the work of the falls had been done

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*The Place of Niagara Falls in Geological History. G. K. Gilbert. Proc. Am. Adv. Sci., vol. XXXV, 1886, pp. 222-223.

† See Trans. Roy. Soc. Can., 1889, p. 132; and Proc. A. A. A. S., 1888, p. 100.

before the upper lakes were turned into the Niagara drainage, for a long time seemed undeterminable, until the features of Foster's flats were used for measuring the amount of work performed in that early episode. This standard has since been confirmed by other phenomena not yet published; and from a different standpoint the distance of the early recession has been agreed to by Prof. Gilbert, who now considers the age of the falls far greater than that formerly suggested by his paper in 1886. From all the available data up to 1894, the writer computed the age of Niagara falls at 32,000 years.[*] Of the various episodes, that of the cataract passing the narrows of the whirlpool rapids still seems the most difficult of explanation; but the writer has recently found that the narrows record a second reduction in the amount of fall in the river, before the present descent was established, thus retarding the recession along this section of the gorge, and increasing in part the time compensation for the reduced amount of work performed. However, further discoveries are necessary to fully explain the phenomenon of the narrows. It now seems probable that the error in determining the time required for the recession of the falls through the section of the whirlpool rapids would not affect the computation of the whole age of the river by more than a few per cent.

No less important than the determination of the age of the river was that of the date when the waters of the Algonquin basin (Huron, Michigan and Superior) were first turned into the Niagara drainage, owing to the warping of the land, with the greatest rise occurring along an axis trending N. 28° E.[†] The date of the diversion of the waters of the upper lakes from the Ottawa to the Niagara valley has been computed by the writer at 7,200 years. This result was obtained from the mean of three distinct methods of computation, varying from 6,500 to 7,800 years.[‡] Mr. F. B. Taylor's more recent estimate gives the range of from 5,000 to 10,000 years.

Niagara as a time piece would be incomplete without indi-

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[*] Duration of Niagara Falls. Am. Jour. Sci., vol. XLVIII, 1894, pp. 455-472.

[†] This direction occurs east of Georgian bay, while at the end of lake Ontario the direction of rise is N. 25° E. See papers by the writer cited before.

[‡] See Duration of Niagara Falls, cited before.

cating the changes in the near future. From the northeastward tilting of the lake region, it was computed that in 5,000 years, not merely Niagara falls would cease to exist, but also that the drainage of the deepest part of the Niagara river at Buffalo (45 feet) would be reversed and turned into lake Erie, whose outlet would then be through lakes Huron and Michigan into the Mississippi river by way of Chicago. This inference was based upon the long delayed discovery of the rate at which the earth's crust has been rising in the lake region,—which was found to be for the Niagara district 1.25 feet per century more than the rate of rise at Chicago.* With this determination it was easy to calculate the rate of terrestrial deformation for other regions,—thus northeast of lake Huron the rise has been found to be two feet per century, and north of the Adirondacks, the warping is progressing at 3.75 feet in a hundred years.

The rate of deformation of 1.25 feet per century, in the Niagara district, was the minimum calculation, with a possible maximum of about 1.5 feet per century. The approximate correctness of the determination has just been confirmed by a paper presented to the American Association, by Prof. G. K. Gilbert, immediately before this communication was read.† He had used the bench-marks at various localities where the fluctuations of the lake levels have been registered the last 20-37 years. While the recorded measurements vary from about one to two and a half inches during the periods of observation, they have been extended over the lake region, with results closely agreeing with the previous determinations of the writer. This will be better understood using Prof. Gilbert's application—namely,—that in 500-600 years, the Erie waters would be on a level with those of lake Huron—in 1,000 years they would overflow the natural divide near Chicago—in 2,500 years, the waters would cascade into the Niagara gorge only during high water--and in 3,000 years, the falls would be entirely drained. These changing conditions, based upon the writer's previously discovered rate of terrestrial deformation, would take—720 years for the Erie and Huron waters to be

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*See Duration of Niagara Falls, cited before

† Modification of the Great Lakes by earth movements. Nat. Geog. Mag., vol. VIII, 1897, pp. 233-247

on the same level; 1,280 years for the overflow into the Mississippi drainage (the artificial canal would reduce this estimate to 720 years); and 2,560 years for the general drainage of the lakes into the Mississippi. In 5,000 years, the whole river as far as Buffalo would be drained towards the south.

In spite of taking the minimum rate of recession and the probable errors the closeness of these results satisfactorily confirms many of the calculations based upon Niagara as a geological chronometer.

This paper, giving the principal results of investigations into the lake history, thus shows the writer to have been greatly affected by the studies of his co-workers. Indeed all of the researches by the different observers have been very much dove-tailed, so that our present knowledge of the history of the great lakes and Niagara falls is the result of the labors of many individuals. Besides the names of those already mentioned, we should add those of Shaler, Tarr, Wright, Russell, Upham, Kibbe, Lincoln, Brigham and Scovill, with the names of Hall and Lyell, too well known to need special mention.

To complete the review mention should be made of the writings of Mr. F. B. Taylor, in connection with his important survey of the Nipissing outlet of the Algonquin basin, and of the dissected shore lines of the upper lakes; and of the important investigation of Central New York by Prof. Fairchild.

EDITORIAL COMMENT.

A Case of Geological Parasitism.

Notwithstanding the grand success, on the whole, of the Seventh International Congress of Geologists that convened at St. Petersburg last August, there were certain features which tended to interrupt considerably the general good feeling that otherwise prevailed during the series of most enjoyable meetings, and which gave rise to not a little adverse comment. It is not that the same tendencies did not exist at previous sessions, but that at the last one they became so promi-

nent as to call for their serious consideration and removal, if the future gatherings are to be successful. The extraordinary generosity of his Imperial Highness the Czar and of the people throughout every part of the great Russian empire in providing means to make the sojourn of the scientific visitors one to be forever remembered by them with unalloyed pleasure, brought forth an unusually large number of persons who wished to take advantage of the "cheap rates" to "do" a country that is out of the path of the average tourist—people who not only had no just claim to being professional geologists, but were not even in sympathy with the science. To this sort of unpleasant imposition no other term than that of parasitism can be appropriately applied.

Of recent years there has been an increasing tendency for persons entirely uninterested in the various subjects to take advantage of scientific meetings on account of the special inducements offered to take desirable trips at small expense. Not the slightest objection can be offered to the attendance, at the sessions, of non-professional persons who are really interested in the different themes, or even to the presence of unsympathetic individuals; all scientists are broadly charitable in this respect. It is, however, the grossest kind of imposition, to say the least, for these scientifically unsympathetic, though perhaps at times thoughtless, people to rush headlong and hoggishly, as they did in Russia, into all the excursions and entertainments, often provided at great expense, crowding out many who were eligible, causing no end of inconvenience, trouble and confusion to the legitimate attendants, and creating the profoundest consternation among the entertainers. This, in spite of the very plain, and yet perhaps too polite, hints by the local committee, months in advance. Common politeness should have clearly and unmistakably indicated the proper course for these ineligibles to pursue. But the local committee was gracious; it swallowed the unexpected and bitter dose as best it could, and put forth its very best efforts to make the occasion pleasant for all—unwelcomed guests as well as especially invited workers—even at an additional cost of many thousand roubles.

Unfortunately the kindly actions of a local committee did not universally prevail, and it will be many a long day before

some of the intruders will care again to face the criticisms received and so amply deserved. Much as direct snubbing is to be regretted in any instance, it was a case that got beyond human endurance. It will serve, however, as a wholesome warning against the increase of similar parasitism in the future. No doubt the experience will lead the next congress, which convenes at Paris in 1900, to adopt early some rigid restrictions as to who shall participate in the excursions and entertainments that may be offered. Each nation, however, moreover, should use its best endeavors not only to send its best representatives as delegates, but should take proper measures to induce all those who are not actually engaged in geological work to have compassion enough on their countrymen not to disgrace them.

While the Americans were by no means the greatest sinners, parasitism among them at the St. Petersburg meeting was so prevalent that a repetition of it to the same extent will cause Americans to lose their present creditable standing among the geologists of the world. More than once during their sojourn in Russia were the American geologists present compelled to bow their heads in shame at the actions of their countrymen who posed as scientists from the new continent, but who had no right whatever to the courtesies that were extended. Other nations were severely afflicted in the same way, but that was no excuse for the existence of the scourge among us. The extent to which the legitimate working geologists of America were made to suffer the stigma cast upon them by their well-meaning, but perhaps thoughtless, associates, is shown by the fact that out of the sixty credited to America, no less than twenty-five had not the slightest excuse for participating, further than attending the general sessions. With certain other nations the percentages were even higher. A hint as to the extent to which this was considered an extra burden carried by the Russian people may be obtained from the fact that out of about 900 who were members of the congress, only 200 invitations to the reception at the Marble palace were sent out by their Imperial Highnesses the Grand Duke and Duchess, and it is not believed that the name of any prominent geologist was omitted.

In order that the experience may not be repeated, it is

necessary to take certain precaution before the convening of the next congress at Paris, three years hence. While the French no doubt will see that the same condition of affairs is not allowed to prevail, it is desirable for each nation to supplement this effort so far as itself is concerned. The first cause of it all, in the past, may be attributed directly to the local committees;though they are not to be blamed, however much future committees may be open to criticism should they not take warning in time to avoid the same pitfall.

The course to pursue is a simple one, notwithstanding the fact that the life of the congress is not continuous. As the next assembly, in 1900, is to be strictly a gathering of geologists, it is only necessary for the local committee at Paris to send out invitations to those whom they know to be bona fide workers in the science. The list may be prepared sufficiently long in advance to be submitted for revision to the vice-president of each country represented in the previous congress. The application for membership of all others may be referred in the same manner to the respective nations. An ample as well as simple test of elegibility is found in the published writings of the persons wishing to become members, so also the immediate members of the families of participants may be readily made associate members, with all privileges except those of voting and participation in the excursions. The suggestion of the last named restriction may sound somewhat severe, but in order to accomplish one of the principal objects of the triennial gathering it is absolutely necessary to limit the number of participants in the trips to the least possible number and to the strictly working geologists. The burdens of past congresses have become at last too heavy to be borne in the future. C. R. K.

REVIEW OF RECENT GEOLOGICAL LITERATURE.

Geological Survey of New Jersey, Annual Report for the Year 1896. JOHN C. SMOCK, State Geologist. Pages xxviii, 377, with 24 plates and a large map. Trenton, 1897.

The administrative report, by Prof. Smock, in 18 pages, gives a comprehensive outline of the work of the survey during 1896; and this is followed by eight reports of its separate divisions.

Prof. Rollin D. Salisbury and Mr. George N. Knapp present their Report of Progress on the Surface Geology in 23 pages, with seven plates. It is found that the Pensauken formation, which McGee and Salisbury have pronounced to be the northward continuation of the Lafayette formation in the more southern states of the Atlantic coastal plain and Gulf region, when traced into the northeastern part of Middlesex county, adjoining the glacial drift, becomes in many places unstratified and incloses glacially striated stones, being almost like till. It was formed contemporaneously with an early extension, perhaps the maximum, of the North American ice-sheet.

Because of this relationship, it seems to me worthy of inquiry whether the correlation with the southern coastal plain formations studied by McGee, Darton, Clark, and others, may be better given as follows: 1. The clay and sand beds of the lower part of the Beacon Hill series, probably marine Miocene; 2. The upper Beacon Hill gravel, equivalent with the Lafayette formation; 3. The great erosion interval between the time of the Beacon Hill gravel and the Pensauken epoch, equivalent with the Ozarkian epoch of Hershey, completing the Lafayette period; 4. etc. The Pensauken, Jamesburg, and Trenton formations, with the Philadelphia brick clay, all of Glacial age, the first belonging to a time of high continental elevation, and the others to the Late Glacial or Champlain epoch of continental depression, together representing the Columbia series in its high level and low level phases. This view, with reference of all the Yellow Gravel series in New Jersey to fluvial deposition, not in the sea, was suggested by the present reviewer in the American Geologist for March, 1895 (vol. xv, p. 204).

Dr. Henry B. Kümmel, in Part II. (pages 25-88, with plate viii), reports the progress of his field work and studies of the Newark system. The sedimentary rocks of this system are divided, in ascending order, into the Stockton, Lockatong, and Brunswick series. Exclusive of the intruded sheets and overflows of trap, the thickness of these three divisions is estimated to be, respectively, 4,700, 3,600, and 12,000 feet, giving a total of 20,300 feet.

Part III is Prof. J. E. Wolff's Report on Archean Geology (pages 89-94, with plate ix), dealing with the eruptive rocks of Sussex county.

Part IV, by Lewis Woolman, includes reports on artesian wells (pages 97-200), and notes on the stratigraphy and fossils of the Fish House black clay and associated gravels, near Camden and Philadelphia, which are referred to the Pensauken series. The fossils comprise *Unio* and *Anodonta* species, *Equus complicatus* Leidy, flattened tree and other plant stems, and peat. Mr. Woolman also notes the occurrence of dinosaur and molluscan fossils in Cretaceous clay marls, and of *Fulgur* and *Venus* casts in Beacon Hill sands near Millville, about 40 miles south of Camden.

The remaining parts of this volume treat of the flood of February 6th, 1896, in northern New Jersey, by C. C. Vermeule; of drainage of the Newark and Hackensack tide-marshes, also by Mr. Vermeule, with a large folded map; of the iron-mining industry, by George E. Jenkins;

and of forestry, with notes of European countries, by John Gifford. The volume is completed with mining statistics for 1896, the catalogue of publications of the survey, and an index. W. U.

Report on the Doobaunt, Kazan and Ferguson Rivers and the Northwest Coast of Hudson Bay, and on Two Overland Routes from Hudson Bay to Lake Winnipeg. By J. BURR TYRRELL. Part F, of the Annual Report of the Geological Survey of Canada, vol. IX, for 1896. Pages 218, with eleven plates and three maps. Ottawa, 1897.

The routes of travel here described extend across an area of about 200,000 square miles, from near the east end of lake Athabasca northward and eastward to Chesterfield Inlet and the west side of Hudson bay. The explorations were carried on in the years 1893 and 1894, the author's return from each expedition being in winter by sledging over frozen rivers and lakes between Fort Churchill and Winnipeg. The country consists mainly of granitic rocks and granitoid gneisses, of Laurentian age, with several large Huronian tracts; but Cambrian sandstone and conglomerate adjoin Athabasca lake and also extend nearly 200 miles west from the head of Chesterfield Inlet.

On the treeless Barren Lands of the north, which comprise the greater part of the country, immense herds of caribou pasture in the summer, retiring southward to the woods in winter. One herd, of which two photographs are given, was estimated to number between one and two hundred thousand.

The contour is only slightly diversified. It presents mostly a vast undulating plain, having an inland altitude of 1,000 to 1,500 feet, with rare hills a few hundred feet higher, and declining gradually eastward to the shores of Hudson bay. Much of the surface is sandy or stony till, with only shallow and ill-defined valleys, of which the author says: "Since the disappearance of the Keewatin glacier, the streams have had very little power of erosion, for they are frozen up most of the year, and each spring, as they open, the ice packs the boulders that form their banks into massive walls which resist erosion almost as effectually as the unbroken rock itself. Besides this, the time since the disappearance of the glacier may not have been very long."

The courses of glacial striation and transportation of drift imply, as the author shows, that the ice-sheet in its departure became divided into several separate areas. The reviewer thinks, however, that the maximum extensions of the confluent North American ice-sheet were nearly contemporaneous from its Laurentide, Keewatin and Cordilleran centers of outflow. The observations of Chamberlin, Todd, and the writer of this review, prove that continuous marginal moraines pass from the Laurentide to the Keewatin ice front in Minnesota and the Dakotas, south of lake Agassiz and also from the east to the west sides of that glacial lake.

Marginal moraines and eskers were noted by Tyrrell in many places throughout the country here reported. After the ice-sheet had mostly disappeared, the land west of Hudson bay lay nearly 500 feet lower than

now, and successive marine shore lines mark stages of the ensuing epeirogenic uplift of the land to its present hight.

Three appendixes are included at the end of this report. The first gives the Chippewyan names of places; the second is a vocabulary of words used by the Inland Eskimos who live on the Kazan and Ferguson rivers; and the third is a list of the plants collected (excepting algæ and fungi), as determined by Prof. John Macoun, with notes of their localities. W. U.

Batesville Sandstone of Arkansas, By STUART WELLER. (Trans. New York Acad. Sci., vol. XVI, pp. 251-285, 1897.)

Until very recently the Ozark region was one of the largest tracts in the country that remained a veritable "terra incognita" to geologists. Of late years, however, workers in different parts of the region brought out, more or less completely, local successions of formations, but these were never paralleled exactly with those of neighboring districts. This was especially true of the later Paleozoic deposits. On the north side of the great dome the formations just referred to were finally brought into strict accordance with the standard sections of the Mississippi basin. On the south side of the uplift, in Arkansas, and Indian territory, little effort was made to compare the various portions of the general section of that region with the more typical localities to the north. In the southern district, also, an entirely new set of names was applied, which in the absence of exact data and knowledge regarding the northern representatives precluded any but the most general comparisons of their probable equivalents. About the only formation of the lower Carboniferous, for instance, that was correlated, with any degree of certainty, with the northern sections was the Boone chert, which was thought to represent, in part at least, the well known Burlington limestone. It was at a subsequent time that the Kaskaskia division was clearly recognized in northwestern Arkansas and the adjoining part of Indian territory, with indications of the St. Louis limestone nearby in Missouri; also farther eastward on the tributaries of the White river the Kinderhook was definitely made out, so that all four of the main subdivisions of the Mississippian series, or Lower Carboniferous, were differentiated around the entire northern two-thirds of the Ozark uplift. Much of the Arkansas part of the dome remained uncorrelated.

It is, then, with special welcome that the results of the recent work of professor Weller, in the Carboniferous of northeastern Arkansas, are received. Under the modest title of "The Batesville Sandstone of Arkansas" appears one of the most important contributions to our knowledge of the geology of the Ozark region that has yet appeared. The succession of the Carboniferous, as represented in the Batesville district and of northern Arkansas generally is shown to be as clearly defined, and with the same subdivision, as in the typical localities along the Mississippi river. The following is the table of equivalent formations:

BATESVILLE SECTION.	TYPICAL SECTION.
Boston limestones and shales.	Kaskaskia limestone and shales.
Batesville sandstone.	Aux Vases sandstone.
Spring Creek limestone and shales.	St. Louis limestone.
Boone cherts.	Ozark [Augusta] limestone.
St. Joe marble.	Kinderhook beds.
Sylamore sandstone.	Basal sandstone of Kinderhook.

Regarding these, the author says, in conclusion:

"The Batesville sandstone has the same stratigraphical position in the Batesville section which the Aux Vases sandstone occupies in the typical section, and the lithologic characters of the two formations are similar. No fossils have as yet been found in the Aux Vases sandstone, but if a fauna were found a mingling of St. Louis and Kaskaskia species, such as are present in the Batesville sandstone fauna would be looked for.

"The strata of the Batesville section were deposited off the southern shore of the same land, from whose eastern shore the strata of the typical section were laid down, hence it is not surprising to find the sequence of the strata almost identical in the two sections.

"The Mississippian series was typically deposited not only along the line of the present Mississippi river, but off the shores and wholly surrounding the ancient Ozark Island. The deposition varied more or less off the different shores of the island, especially during the latter half of the period, when the body of land ceased to be entirely surrounded by water, by being partially or wholly joined to the mainland toward the north; the lower formations, however, included in the Kinderhook and Osage groups, may be expected to have a similar development on all sides of the ancient island."

The paper contains the descriptions and illustrations of a number of new species of fossils that form a part of a rather extensive fauna which was found near the base of the sandstone, and also critical annotations on these and a number of others. The relations of the faunas of the Batesville sandstone and of the Maxville limestone of Ohio are also discussed. The brief clear statement regarding the stratigraphy of the Batesville region, and of the typical Mississippian section makes the theme complete and adds greatly to the usefulness of the account.

There are one or two points in the article that might be open to criticism. One is the use of the word "group" in a sense that is now generally abandoned by geologists, who have given it an exact meaning in another connection—for a larger "group" of formations; though it is recognized that many paleontologists still persist in applying the term in a general, indefinite or loose way. Another point concerns the myth of the Ozark isle. Of late the "Ozark island" has been also used by the same author, as well as others, as the foundation of some attractive and far-reaching generalizations regarding the distribution of Devonian and early Carboniferous faunas, and of the land and water areas of that time. The idea of the existence, from Cambrian times, of an Ozark island was promulgated by some of the older geologists, who visited the region when our knowledge of the geological events that transpired in that part of the present continent was very much less complete than now. Although of late special attention has been repeatedly called to the fact, and ample evidence set forth, it seems well

nigh impossible to eradicate the antiquated views which still continue to creep into the current literature relating to the region. Every bit of evidence that has been obtained in regard to the geological history of the Ozark uplift points conclusively to the fact that not only was the dome or "island" character of the area not acquired until a very late date, geologically speaking, during Tertiary times—the older formations having been removed down to the Silurian or Cambrian during the Cretaceous · base-leveling process that prevailed over a large area of this portion of the continent—but that during the later Paleozoic, up to the epoch in which the coal deposits were laid down, sedimentation was uninterrupted over the entire region. In substantiation of the statement that the Devonian and Lower Carboniferous (up to the Kaskaskia) strata once extended unbrokenly over the whole of the present Ozark dome, but were almost entirely removed through subsequent erosion at a later date, one has only to point to the fact that remnants of highly fossiliferous beds of undoubted Devonian and Lower Carboniferous age are still found on the highest portions of the central parts of the uplift.

C. R. K.

MONTHLY AUTHORS' CATALOGUE
OF AMERICAN GEOLOGICAL LITERATURE, ARRANGED ALPHABETICALLY.*

Ball, T. H.

The Lake Michigan and Mississippi Valley water shed. (Indiana Acad. Sci., Proc. 1896, pp. 72-73, 1897.)

Ball, T. H.

Some notice of streams, springs, wells and sand ridges in Lake county, Indiana. (Indiana Acad. Sci., Proc. 1896, pp. 73-75, 1897.)

Carter, O. C. S.

The upper Schuylkill river. (14 pp.; reprint from Jour. Franklin Inst., Nov. 1897.)

Chamberlin, T. C.

Supplementary hypothesis respecting the origin of the loess of the Mississippi valley. (Jour. Geol., vol. 5, pp. 795-802, Nov.-Dec. 1897.)

Chamberlin, T. C.

Studies for students. The method of multiple working hypotheses. (Jour. Geol., vol. 5, pp. 837-848, Nov.-Dec. 1897.)

Corthell, E. L.

The delta of the Mississippi river. (Nat. Geog. Mag., vol. 8, pp. 351-354, Dec. 1897.)

Cragin, F. W.

Discovery of marine Jurassic rocks in southwestern Texas. (Jour. Geol., vol. 5, pp. 813-820, Nov.-Dec. 1897.)

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*This list includes titles of articles received up to the 20th of the preceding month, including general geology, physiography, paleontology, petrology and mineralogy.

Dall, W. H. (Guppy, R. J. L., and)

Descriptions of Tertiary fossils from the Antillean region. (U. S. Nat. Museum, Proc., vol. 19, no. 1110, pp. 303-331, pls. 27-30, 1897. Extras issued May 30, 1896.)

Daly, R. A.

Studies in the so-called porphyritic gneiss of New Hampshire. II. (Jour. Geol., vol. 5, pp. 776-794, Nov.-Dec. 1897.)

Gilbert, G. K.

Joseph Francis James. (Am. Geol., vol. 21, pp. 1-11, pl. 1, Jan. 1898.)

Guppy, R. J. L. (and Dall, W. H.)

Descriptions of Tertiary fossils from the Antillean region. (U. S. Nat. Museum, Proc., vol. 19, no. 1110, pp. 303-331, pls. 27-30, 1897. Extras issued May 30, 1896.)

Ingall, E. D.

Section of mineral statistics and mines. Annual Report for 1896. (Geol. Surv. Canada, Ann. Rept., vol. 9 [1896], pt. S, 172 pp., 1897.)

Iwasaki, C.

Andendiorite in Japan. (Jour. Geol., vol. 5, pp. 821-824, Nov.-Dec. 1897.)

James, J. F.

Sketch of, by G. K. Gilbert. (Am. Geol., vol. 21, pp. 1-11, pl. 1, Jan. 1898.)

Merriam, J. C.

The geologic relations of the Martinez group of California at the typical locality. (Jour. Geol., vol. 5, pp. 767-775, Nov.-Dec. 1897.)

Preston, H. L.

On iron meteorites, as nodular structures in stony meteorites. (Am. Jour. Sci., ser. 4, vol. 5, pp. 62-64, Jan. 1898.)

Salisbury, R. D.

On the origin and age of the relic-bearing sand at Trenton, N. J. (Science, n. ser., vol. 6, pp. 977-981, Dec. 31, 1897.)

Schuchert, Charles.

On the fossil phyllopod genera, Dipeltis and Protocaris, of the family Apodidæ. (U. S. Nat. Museum, Proc., vol. 19, no. 1117, pp. 671-676, pl. 58, 1897. Extras issued May 30, 1897.)

Smith, W. S. T.

A note on the migration of divides. (Jour. Geol., vol. 5, pp. 809-812, Nov.-Dec. 1897.)

Spencer, J. W.

On the continental elevation of the Glacial period. (Geol. Mag., new ser., dec. 4, vol. 5, pp. 33-38, Jan. 1898.)

Squier, G. H.

Studies in the driftless area of Wisconsin. (Jour. Geol., vol. 5, pp. 825-836, Nov.-Dec. 1897.)

Stone, G. H.

The granitic breccias of the Cripple Creek region. (Am. Jour. Sci., ser. 4, vol. 5, pp. 21-32, Jan. 1898.)

Tyrell, J. B.

Report on the Doobaunt, Kazan and Ferguson Rivers and the northwest coast of Hudson bay and on two overland routes from Hudson bay to lake Winnipeg. (Geol. Surv. Canada, Ann. Rept., vol. 9 [1896], pt. F, 218 pp., 11 pls., 3 maps, 1897.)

Wadsworth, M. E.

Zirkelite—a question of priority. (Science, n. ser., vol. 7, p. 30, Jan. 7, 1898.)

Walcott, C. D.

Cambrian Brachiopoda: Genera Iphidea and Yorkia, with descriptions of new species of each, and of the genus Acrothele. (U. S. Nat. Museum, Proc., vol. 19, no. 1120, pp. 707-718, pls. 59-60, 1897. Extras issued Aug. 27, 1897.)

Weller, Stuart.

Cryptodiscus, Hall. (Jour. Geol., vol. 5, pp. 803-808, Nov.-Dec. 1897.)

White, I. C.

The Pittsburg coal bed. (Am. Geol., vol. 21, pp. 49-60, Jan. 1898.)

White, T. G.

A contribution to the petrography of the Boston basin. (Boston Soc. Nat. Hist., Proc., vol. 28, no. 6, pp. 117-156, pls. 1-5, Dec. 1897.)

Whitfield, R. P.

Observations on the genus Barrettia, Woodward, with descriptions of two new species. (Am. Mus. Nat. Hist., Bull., vol. 9, pp. 233-246, pls. 27-38, Nov. 19, 1898.)

Wieland, G. R.

The protostegan plastron. (Am. Jour. Sci., ser. 4, vol. 5, pp. 15-20, pl. 2, Jan. 1898.)

Winchell, N. H.

Determination of the feldspars. (Am. Geol., vol. 21, pp. 12-49, pls. 2-8, Jan. 1898.)

CORRESPONDENCE.

ZIRKELYTE: A QUESTION OF PRIORITY. In the *Mineralogical Magazine*, volume XI, pp. 86-88 (read June 18th, 1895) is described a new mineral containing zirconium, titanium, lime, iron, etc., under the name of zirkelite. This paper was prepared by my friend, Dr. E. Hussak, and by Mr. G. T. Prior.

Later, Mr. Prior (l. c. pp. 180-183, read Nov. 17, 1896) published an analysis of the same mineral.

I wish to protest against the use of the name zirkelite for this mineral on the ground of the prior use of it to designate a commonly occurring rock belonging to the basaltic family.

When two subjects are so intimately connected as mineralogy and petrography, it does not seem to be for the interest of science that

names should be duplicated in them. So true is this, that I abandoned the name rosenbuschyte, which I had given to a class of rocks in honor of professor Rosenbusch, because only a few weeks previously it had been employed to designate a new mineral.

The term zirkelyte was used by me in 1887, or seven years before it was taken by Messrs. Hussak and Prior. (See "Preliminary Description of the Peridotytes, Gabbros, Diabases and Andesytes of Minnesota." Bulletin No. 2. Geological Survey of Minnesota, 1887, pp. 30-32). It was used to designate the commonly occurring altered conditions of basaltic glassy lavas which are often called diabase-glass, etc. Zirkelyte occurs forming the entire mass of thin dikes, and the exterior parts of many dikes of diabase and melaphyr, as well as the surface of old lava flows like the melaphyrs and diabases of lake Superior, Newfoundland and elsewhere. Zirkelyte holds the same relation to tachylyte that diabase and melaphyr do to basalt, i. e., an older and altered type. The macroscopic and microscopic characters of this rock were given in the locality cited above.

The term zirkelyte was again used in the same way in my "Report of the Geological Survey of Michigan" for 1891-1892; (1893, pp. 90, 97, 138, etc).

It was also published in my classification of rocks given in the catalogue of the Michigan College of Mines (Michigan Mining School). 1891-1892, p. 104; 1892-1894, Table XI; 1894-1896, Table XI.

Further, the term zirkelyte is defined in accordance with my usage in Loewinson-Lessing's "Petrographisches Lexikon," 1893, p. 252; and accounts of it are given in the Neues Jahrbuch für Mineralogie, 1893, II, p. 292, and in Kemp's "Handbook of Rocks," 1896, p. 170.

Michigan College of Mines, Dec. 8, 1897. M. E. WADSWORTH.
Houghton, Michigan.

PERSONAL AND SCIENTIFIC NEWS.

MR. S. A. MILLER, of Cincinnati, Ohio, died on Dec. 19, aged 61 years. He is known for his work in paleontology, and more especially for his book entitled "North American Geology and Palæontology," which appeared in 1889. Two appendices to this book have been published. During the last few years Mr. Miller contributed many paleontological articles to the Bulletin of the Illinois State Museum of Natural History.

MR. NOAH FIELDS DRAKE, a graduate student of geology at Stanford University, has accepted a position as professor of mining engineering and geology at Tien Tsin University, China.

PROF. N. H. WINCHELL, editor of this journal, sailed from New York for Havre on Jan. 15. He expects to spend several

months in Paris, engaged in investigating the petrology of the crystalline rocks of northeastern Minnesota. The results of his work are to be published in one of the reports of the Geological and Natural History Survey of Minnesota.

THE GEOLOGICAL SOCIETY OF WASHINGTON at its meeting of December 22rd, elected the following officers for the ensuing year: President,, Arnold Hague; vice-presidents, J. S. Diller and Whitman Cross; treasurer, M. R. Campbell; secretaries, C. Willard Hayes and T. W. Stanton; members-at-large of council, S. F. Emmons, G. P. Merrill, W. H. Weed, David White and Bailey Willis.

THE GEOLOGICAL SOCIETY OF AMERICA at its meeting held in Montreal the last week in December, elected the following officers: President, J. J. Stevenson; first vice-president, B. K. Emerson; second vice-president, G. M. Dawson; secretary, H. L. Fairchild; treasurer, I. C. White; editor J. Stanley-Brown; librarian, H. P. Cushing; councillors, W. M. Davis, Robert Bell and M. E. Wadsworth. The membership roll of the Society, including four fellows elected at this meeting, contains 246 names. The treasurer's report shows that the Society's financial condition is prosperous, thus making it possible to illustrate more fully future publications.

NEW YORK ACADEMY OF SCIENCES, Section of Geology, Dec. 20th, 1897.—The first paper of the evening was by Mr. Arthur Hollick, entitled "Recent Explorations for Prehistoric Implements in the Trenton Gravels, Trenton, N. J." Dr. Hollick gave in his paper a summary of the present understanding of the artefacts found in the Trenton gravels, a more complete statement of which has already been published in Science for November 5, 1897. The second paper of the evening was by Prof. J. F. Kemp, entitled "Some Eruptive Rocks from the Black Hills." Prof. Kemp summarized the geological features and history of the Black hills, and gave a bibliography of the works concerning these deposits. He then mentioned the occurrence of some leucite bearing rocks, in the northern part of the hills, similar in character to those which occur in but few other places in this country, as in Wyoming, Montana, Lower California, and New Jersey, near the Franklin furnace. RICHARD E. DODGE *Secretary.*

THE MINNESOTA ACADEMY OF NATURAL SCIENCES at its last regular meeting (Jan. 5) elected the following officers for the year 1898: Prof. N. H. Winchell, president; Prof. D. T. MacDougal, vice-president; Mr. A. D. Roe, recording secretary; Dr. C. P. Berkey, corresponding secretary; Mr. E. C. Gale, treasurer. At this meeting steps were taken looking toward an at least temporary change from the former monthly meeting to more important meetings to be held less frequently.

It is possible that one meeting a year will be held away from Minneapolis, the home of the Academy. On Dec. 28, 29 and 30, meetings in celebration of the twenty-fifth anniversary of the Academy were held, at which twenty papers were presented. Among these the following pertained to geology:

"On a little known larviform crinoid from the lower Paleozoic, and comparison with the living Antedon," by F. W. Sardeson, who discussed more particularly the origin of the centro-dorsal plate of Antedon, tracing it apparently to three, five and six infrabasal plates, respectively, in Paleozoic crinoids.

"The glacial lake Agassiz," by Warren Upham. The facts presented are found in the author's detailed report on this subject (Mon. 25 of the U. S. Geological Survey.)

"Volcanic fragmental rocks at Taylors Falls, Minnesota," by C. B. Berkey. This subject is discussed in an article by the author in the December number of this journal.

"The recession of the glacier from the Lake Superior region," by A. H. Elftman. The substance of this paper can be found in the author's article in this number of this journal.

"Significance of the fragmental eruptive débris at Taylors Falls," by N. H. Winchell. The author regards this eruptive débris as in the main an oceanic deposit, forming, in part at least, a true basal conglomerate. Thus the diabase flows at Taylors Falls are separated into two parts by an interval of erosion followed by one of oceanic deposition. This unconformity and the basal conglomerate are correlated with similar phenomena in the Lake Superior region which enable us to separate the Keweenawan eruptives into a lower (Norian) and an upper series.

"Field notes in New Mexico geology," by C. L. Herrick. Some of the more important and interesting points in the geology of this district were discussed and especial attention was called to points which offered promising fields for investigation.

"The drift in southwestern Minnesota and northwestern Iowa," by H. F. Bain. Detailed observations in Plymouth county, Iowa, and the surrounding districts, showing the presence of several till, gravel and loess deposits, were given and the following preliminary interpretation was presented: (1) Kansan drift; (2) Iowan drift; (3) high level gravels connected with Wisconsin moraines; (4) erosion of river valleys; (5) sheet loess; (6) Anadonta terrace (?); (7) Missouri River loess proper; (8) Later terraces in the loess; (9) Wisconsin gravel trains proper.

"The end of the ice age in Minnesota," by Warren Upham. The author presented the main facts of the ice retreat across the state, dwelling chiefly on the series of terminal moraines and the larger glacial lakes. Of the latter the two lakes in the Minnesota River valley were especially discussed.

"Certain resemblances between the Archean in Minnesota and in Finland," by N. H. Winchell. The resemblances between the Archean of these two localities both in sequence of events and in lithology, were shown to be comparatively close and the Minnesota series was more especially discussed. The sequence in this state is as follows, beginning with the most recent: (1) eruptive granite, at Snowbank lake and on the Giants range; (2) Upper Keewatin sediments, separated by an unconformity from (3) eruptive granite, at Saganaga lake; (4) Lower Keewatin or Kawishiwin sediments and contemporary eruptives; the rocks of this age consist very largely of "greenstones" most of which the author regards as water deposited fragmental volcanic débris.

"Relations of the Saganaga granite to the surrounding rocks," by U. S. Grant. Only that part of the granite lying in Minnesota (at the northwestern corner of Cook county) was discussed. The granite lies unconformably below the Animikie on the southeast, is intrusive into the "greenstones" on the south, which are also unconformable below the Animikie, and is unconformable below the Upper Keewatin on the west. Attention was called to the fact that a very large portion of the "greenstones" of this part of the state shows no evidence of having been deposited in the water, and also to the probability of the separation of the Lower Keewatin into two unconformable series, both of which contain much "greenstone." The author regards the "greenstones" immediately adjoining the Saganaga granite on the south, and also those just south of the Basswood granite, as probably belonging to the lower series (Basement Complex), while the "greenstones" associated with the jaspilytes and iron ores of the Keewatin are regarded mainly as eruptives of later date than the jaspilytes of the upper series.

A GEOLOGICAL SURVEY OF THE SOUTH AFRICAN REPUBLIC has recently been decided upon by the government of that state and has been placed under the direction of Dr. G. A. F. Molengraaff, as state geologist. The results of this survey will be published by means of annual reports and from time to time of separate papers, accompanied by maps. A geological museum and a library will be established at Pretoria in connection with the survey.

DAS ANTLITZ DER ERDE, by Ed. Suess, has been translated into French under the direction of Emm. de Margerie. The translation is entitled "La Face de la Terre," and it has an introduction by Marcel Bertrand. This work is published by Armand Colin & Co. (5 rue de Mézières, Paris), and the first volume has recently been issued.

THE MARSH PALEONTOLOGICAL COLLECTIONS.

At the meeting of the Yale Corporation, held on the 13th inst., O. C. Marsh, professor of paleontology, formally presented to the University the valuable scientific collections belonging to him, now deposited in the Peabody Museum. These collections, six in number, are in many respects the most extensive and valuable of any in this country, and have been brought together by Prof. Marsh at great labor and expense, during the last thirty years. The paleontological collections are well known, and were mainly secured by Prof. Marsh during his explorations in the Rocky mountains. They include most of the type specimens he has described in his various publications.

The collection of vertebrate fossils is the most important and valuable of all, and includes, among many others, (1) the series of fossils illustrating the genealogy of the horse, as made out by Prof. Marsh, and accepted by Huxley, who used it as the basis of his New York lectures; (2) the birds with teeth, nearly two hundred individuals, described in Prof. Marsh's well-known monograph "Odontornithes"; (3) the

gigantic Dinocerata, several hundred in number, Eocene mammals described in his monograph on this group; (4) the Brontotheridæ, huge Miocene mammals, some two hundred in number; (5) pterodactyles, or flying dragons, over six hundred in number; (6) the mosasaurs, or Cretaceous sea-serpents, represented by more than fifteen hundred individuals; (7) a large number of dinosaurian reptiles, some of gigantic size. Besides there are various other groups of mammals, birds and reptiles, most of them including unique specimens.

Additional collections comprise extensive series of fossil footprints, invertebrate fossils, recent osteology, American archeology and ethnology and minerals.

The main conditions of the gift, which is for the benefit of all departments of the University, are that the collections shall remain in a fire-proof building and under the control of Prof. Marsh during his life; after that under the charge of the trustees of the Peabody Museum, and, finally, that type specimens shall not be removed from the museum building.

From the scientific point of view the value of the collections is beyond price, each one containing many specimens that can never be duplicated and already are of historical interest. Altogether this is the most important gift to natural science that Yale has yet received.

THE INDIANA ACADEMY OF SCIENCE held its thirteenth annual meeting at Indianapolis, on Dec. 29 and 30. Eighty papers were presented, of which the following pertained to geology:

"Formation of quicksand pockets in the blue clay of South Bend." W. M. Whitten.

"Preliminary work for the approximate determination of the time since the retreat cf the first great ice sheet." G. Culbertson.

"Some faults of Indiana Coal Measures." G. H. Ashley.

"A section from Hanover to Vincennes." J. F. Newsom.

"The Knobstone groups in the region of New Albany." J. F. Newsom.

"Notes on the geology of Mammoth Cave." R. E. Call.

"The upper limits of the Knobstone in the region of Borden." L. H. Jones.

"Four sections across the Knobstone group." L. F. Bennet.

"Notes on Indiana geology." J. A. Price.

"An old river channel in Spencer county." A. C. Veach.

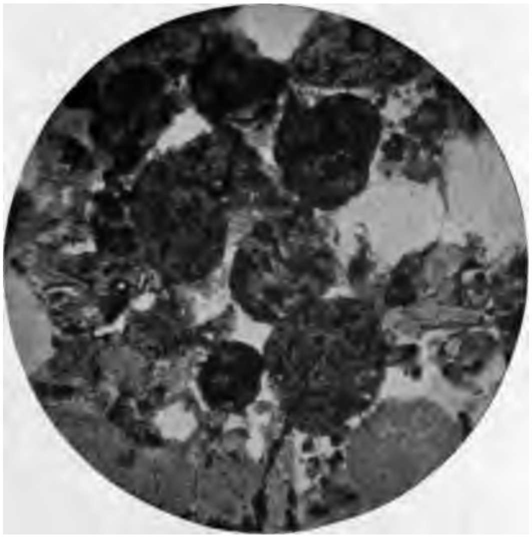

FIG. 1.—VOLCANIC TUFF.
(Magnified 40 diameters.)

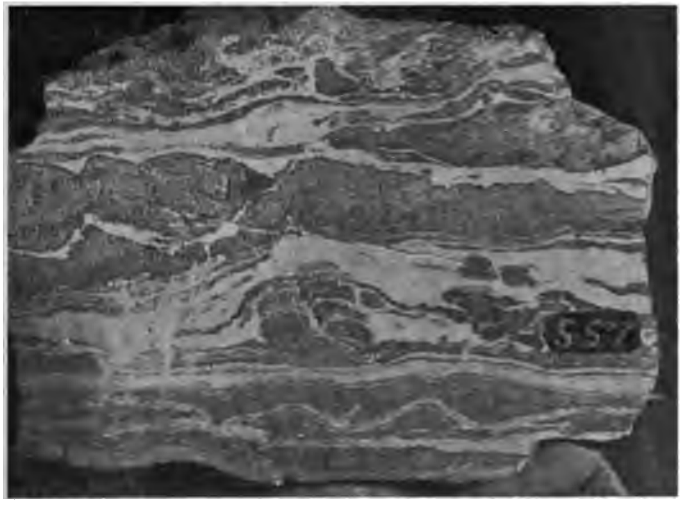

FIG. 2.—ST. LAWRENCE SHALES.
(Reduced one-third.)

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GEOLOGY OF THE ST. CROIX DALLES. II.

By Charles P. BERKEY, Minneapolis.

(Plates XII and XIII.)

PART. II.—MINERALOGY.

CHAPTER I. *Lithology of the Sedimentary Rocks.*

Magnesian Series. A description summarizing the lithologic character of the Jordan sandstone and St. Lawrence shales has been published by Hall and Sardeson.[*] There are few things of sufficient note, in the very limited extent of these rocks within this area, to demand extended discussion. The St. Lawrence, however, at this locality presents a splendid development of alternating bands of sand and green shale, as illustrated in an accompanying figure. The hand specimens from which the photograph was taken were obtained at the foot of the falls at Osceola and belong to the St. Lawrence formation. It is especially noticeable that the sandstone bands are quite pure and in sharp contrast with the green shale bands. This contrast holds good even where the bands are very irregular. It seems to indicate that the original material came either from two very different sources, or at very different rates of accumulation, or that this was the scene of greatly disturbed sedimentation, such as might be occasioned by an unstable ocean current or in a shallow bay subject to violent storms.

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[*] Bull. Geological Society of America, vol. III, 1892, p. 345.

Mention is made of the sandstone conglomerate in another chapter. The pebbles of this conglomerate are well rounded and of the ordinary sandstone type. A few small grains of diabase are found in it. The cementing substance is calcareous, but it does not usually produce a rock of great resistance. In the present condition of both pebbles and matrix a sandstone is formed which, in common with all the sandstones of this area, is too friable for any but the most transient structures.

A specimen of quartzyte was taken from the St. Lawrence near a contact of the sedimentaries with the diabase. But such a development is extremely local in extent.

Basal Sandstone Series. This term is used throughout the paper for a group of sandstones,* shales and conglomerates, situated between the St. Lawrence formation and the underlying igneous floor. These sandstones and shales of the St. Croix Dalles area, as is shown in a former chapter, are separable into three lithologically well defined subdivisions, the uppermost being a sandstone, the middle one composed of a glauconitic sandstone and green shales, and the lowermost including the calcereous, pyritiferous, and argillaceous shales. But below all these, though not exposed in this area, is a thick sandstone† which in many other localities constitutes more than one-half of the total thickness of the series.‡

The upper member, the Franconia sandstone, is a rather fine grained quartz sandstone. The uniform white color varying locally to brown or yellow through ferric oxide stains, the rather angular character of the grains, the porous and friable nature of the stone, the development of minute micaceous flakes among the sand grains, the complex veining produced locally by infiltrated iron oxide, a thick-bedded structure exhibited by exposed bluffs, thin seams of greenish clay shale frequently magnifying the bedded appearance and the general lack of calcareous matter are characteristic of the

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*Owen: Geological Survey of Wisconsin, Iowa and Minnesota, 1852, p. 49.
Chamberlin: Geol. Wis., vol. IV, 1882, p. 39.
Winchell: Final Report Minn. Geol. Survey, vol. II, 1888, p. 407.
Hall and Sardeson: Bull. Geol. Soc. Am., vol. III, 1892, p. 338.

†Geol. Wis., vol. I, 1883, p. 121.

‡C. W. Hall, Artesian Well-boring in S. E. Minnesota, Bull. Minn. Acad. Nat. Sciences, vol. III, no. 1, 1889, p. 138.

Franconia sandstone. The few fossils which occur in limited horizons are casts from which all traces of the original shells have been removed. A peculiarly regular distribution of an iron compound, although the forms outlined by it cannot be identified, is believed to indicate the position of some soft-bodied forms, perhaps plants. Copper minerals are not uncommon, but are always in small quantities and are usually in the form of carbonates.

The green-sand and shale member, the Upper Dresbach, is characterized by a bright or dark green to a greenish gray color. The comparatively large and more evenly rounded quartz grains in the upper portions of the subdivision, the abundance of glauconite in the quartzose beds, a shaly and thin-bedded appearance of exposed portions and a generally friable nature are typical of these beds. An abundance of broken but undecomposed shells, an occasional development of calcareous cementation, cross-bedding in the green-sand bed and the occurrence of several accessory minerals both original and secondary—altogether make the green-sand and shale member a characteristic one. Occasionally large pebbles of quartz are found, and in one instance a pebble of quartzyte was observed. Travertine, apatite crystals of microscopic size, copper carbonate and iron oxide stains constitute the principal accessory minerals.

The calcareous and pyritiferous shales, called Lower Dresbach, are distinguished from the middle member by differences which to some extent are the result of the peculiar local conditions under which they were formed. They occupy the long, narrow, pre-Cambrian valley between two diabase ridges now followed by the St. Croix river north of the Dalles. This valley probably became a secluded bay on the margin of the Cambrian sea coast in whose shelter myriads of animal forms found a favorable environment. Among the most pronounced characters of this member are:—the highly calcareous content which in many places develops numerous layers of limestone from one to three inches in thickness throughout a vertical range of 40 or 50 feet; an abundance of fossil remains of the Lingulepis type furnishing a plentiful supply of the carbonates; and a development in this shale of secondary concretionary pyrite, which furnishes by alteration the sulphates of iron

and associated compounds. The argillaceous shale at the base of the exposed column is greenish gray in color. The sand present in it occurs in small, irregularly distributed areas, giving a mottled appearance to the hand specimens. Some of these sand patches have a regular outline that may indicate organic association. Linguloid fragments are rare. A micaceous mineral in small scales is accessory.

CHAPTER II. *Lithology of the Igneous Rocks.*

Several descriptions of these rocks have been published* and the lithologic character of the typical species is so well known as to require no further attention than the following brief paragraph as a summary. The rock varies from yellowish green to greenish black in color. It is often porphyritic and frequently amygdaloidal and pseudo-amygdaloidal. Usually it is rather finely crystalline and nearly always very much altered from its original mineral composition. Lustre-mottling is common. Microscopic examination reveals the connection between this lustre mottling and the ophitic structure represented by the intergrowth of augite and plagioclase. Besides these two minerals, magnetite and pyrite occur as primary constitutents. The secondary constitutents are quartz, chlorite, epidote, apatite, calcite and a grayish white granular substance whose identity is undetermined.

This rock has been called a melaphyr by Pumpelly, a melaphyr porphyry by Kloos and Streng, trap by Winchell, porphyritic trap by Owen, a diabase also by Kloos and Streng, and an epidote diabase amygdaloid by Pumpelly. Kloos and Streng call this rock melaphyr porphry, but point out that olivine and an amorphous matrix are wholly wanting, while both the essential constitutents and the alteration products common among diabase are present; and the conclusion is

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*Owen: Geol. Survey of Wis., Iowa and Minn., 1852, p. 164.
Kloos: Zeitschrift d. Deutsch. Geol. Gesells., 1871, p. 417. Trans. by Winchell: 10th Ann. Rept. Minn. Geol. and Nat. Hist. Survey, 1881, p. 175.
Kloos and Streng: Neues Jahrbuch fur Min. Geol. und Paleont., 1877, p. 31. Trans. by Winchell: 11th Ann. Rept. Minn. Geol. and Nat. Hist. Survey, 1882, p. 30.
Kloos: Zeitschrift d. Gesells. für Erdkunde zu Berlin, Bd. XII. 1877. Trans. by Winchell: 19th Ann. Rept. Minn. Geol. and Nat. Hist. Survey, 1890, p. 81.
Chamberlin (Strong): Geol. Wis., vol III, 1880, pp. 365-428.

reached that the rock could with equal correctness be called a "diabase."

Local variations of the diabase. Although there is a general similarity in the different outcrops over the whole area, it frequently happens that very unlike varieties are formed within a few feet in the same exposure. In many cases also this difference is not reducible to any known law of position. Porphyritic phases occur immediately adjacent to compact and uniform finely crystalline phases in the same bed and at the same level. This can be said also of many examples of the amygdaloid and pseudo-amygdaloid. In general, however, the porphyritic varieties are most prominent in the upper flows,* while the ophitic character is best seen in the lower flows. These extremes of variation are noted below.

Lustre-mottled Diabase. This variety forms the bases of nearly all of the descriptions of the rocks of this locality heretofore published. It is the commonest phase of the compact uniformly crystalline rock. Its greatest development is in the vicinity of the Dalles, although not confined to that outcrop. On weathered surfaces it is pitted and brown-colored from the development of secondary products. On fresh fractures the rock is greenish-black and exhibits numerous spots over the surface which reflect light from a single cleavage plane. These spots are augite areas, and imbedded in them are many feldspar crystals, the two minerals producing a typical ophitic structure. Other minerals are magnetite and secondary chlorite, epidote, quartz, and kaolin. Not even in the freshest sections has there been found a grain of olivine or a fragment of original glassy matter.

Porphyritic Diabase. At many localities the diabase shows a marked porphyritic development. The phenocrysts are of plagioclase feldspar near labradorite in extinction, from gray to brick red in color, and in size reaching a length of two or three inches. The most persistent and extensive occurrences of the porphyritic diabase are in the series of outcrops in sections 13, 24 and 25, T. 34 N., R. 19 W., in the southern portion of Taylor's Falls village along lower Mill street, and in several localities on the Wisconsin side of the river. It is always limited in extent. A specimen collected in S. E. ¼ S.

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*Owen: Geological Survey of Wis., Iowa and Minn., 1852, p. 164.

E. ¼ Sec. 1, T. 33 N., R. 19 W., exhibited the porphyritic phase developed to an unusual degree. The phenocrysts constitute nearly one-half the total bulk of the rock. On weathered surfaces these feldspars are much altered, the resultant products being chiefly kaolin, quartz, chlorite and epidote. No constant structural relation seems to obtain, although the higher and later flows exhibit a greater tendency to the porphyritic development than do others.

Amygdaloidal Diabase. The amygdaloidal zones are not well developed in this area. Excessive alterations in the upper portions of the several flows has apparently destroyed any amygdaloidal structures which may have been present. Pumpelly and Irving have noted in the rocks of the Keweenaw series* a similar condition. In a few cases, however, the true amygdaloidal character is beyond question, and many boulders of the conglomerate are also true amygdaloids. The minerals filling the amygdules are chiefly quartz, chlorite and epidote.

The pseudo-amygdaloid† is the most extensive alteration development in these rocks. Chlorite is the first and most common product, while quartz, epidote, calcite and feldspar are abundant in varying quantities.

Schistose Structure in the Diabase. Locally and notably within the village of Taylor's Falls occur limited areas of a grayish blue tough rock which exhibits schistose structure. The rock is confined to the separation zones between the flows, and in one instance it is in contact with an enclosed fragmental bed. A specimen taken from above the boat landing at Taylor's Falls, at the contact between the pot-hole bench and the base of the overlying flow exhibits crumpling to a limited extent.

Flowage. In places a wavy banding parallel to the general trend of the flow is readily observed. Locally this banding is evident in the completely altered phases of the rock, while at other places the structure is more conspicuous in the fresher and more finely crystalline diabase. This struc-

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*Geology of Wisconsin, vol. III, 1880, p. 32.
U. S. Geol. Survey, Monograph V, 1884, p. 136.

†Pumpelly: Metasomatic Development of the Copper Bearing Rocks of Lake Superior. Proc. Am. Acad. Arts and Sciences, vol. XIII, 1878, p. 268.

ture seems to be due to flowage. The microscope adds nothing to the distinctness of these bands. They are the only traces of flowage structure to be found in this rock with the exception of that clearly shown in certain grains of the volcanic tuff.

The ophitic texture so abundantly developed, the mineral constitution of these rocks and their holocrystalline condition are characters belonging to a "diabase."

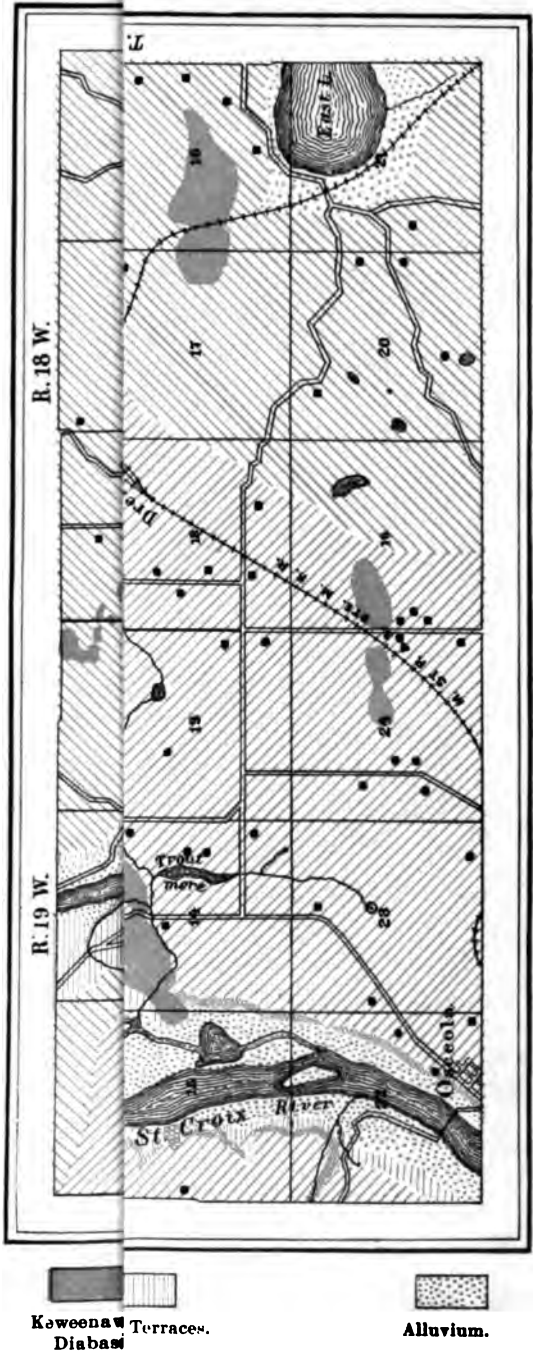
The porphyritic, ophitic and other structures developed in the rock necessitate some qualifying terms. But the fact that all these varieties are only local phases of one parent rock, whose definition may well be broad enough for any or all of them, leads to the conclusion that this igneous rock belonging to the St. Croix Dalles area is most properly designated a "diabase." The terms "porphyritic diabase," "ophitic diabase" and "amygdaloidal diabase" are explanatory of its local variations.

Volcanic Breccias. In the immediate vicinity of the upper Dalles on both sides of the St. Croix river loose pieces of breccia were found. Subsequently this breccia was found in place just above the public school building in Taylor's Falls. The fragmental nature of the rock is not readily apparent, for the rock in place is as hard and compact as other portions of the outcrop. But on closer inspection it is seen that the fragments of diabase are angular, irregular and of all sizes, and lie imbedded in a matrix of finely crystalline secondary minerals, chiefly epidote and quartz. It occurs in one of the division zones between two flows. The occurrence of a breccia was not noted until after a division plane between two flows had been determined upon at this point entirely upon other characters. Later the discovery of an ash at the points previously determined upon as divisions between flows came as a very welcome proof of the accuracy of other observations.

A breccia results at the contact of two lava flows whenever the earlier one presents a surface sufficiently craggy and vescicular for crushing into a broken mass; or whenever the later flow supports at its front a particularly abundant crop of cooled surface-cakes and cindery debris, which are continually rolled beneath the advancing stream.

Associated with the breccia is a volcanic tuff. Together these fragmental rocks are proof of the existence of a series of successive lava flows in this geographic division of the Keweenawan of the Lake Superior basin.

The Volcanic Tuff. A fragmental rock of varying degrees of coarseness has been found in place between several of the flows in the village of Taylor's Falls. Near the intersection of Government and West streets occurs the most extensive development of this type of rock. Together with the breccia which accompanies it there is a total thickness of about twenty feet at this one point. No differences from the ordinary diabase are readily noticed at a little distance, for the same hardness and colors and surface contours prevail in this as in other portions of the outcrop. At no other place, however, is the fragmental nature of beds corresponding to this so easily recognized. It is in so small amount between most of the flows as to readily escape observation until a knowledge of the rock structure of the district obtained from other data is made use of in scrutinizing the most favorable points. Upon closer inspection the clastic character cannot escape notice. The individual particles vary in size from mere dust to the size of an ordinary sand grain, and in the amount of abrasion to which they have been subjected from roughly angular to beautifully rounded grains. The upper portion of the bed is stratified and the banding due to water sorting is apparent in many specimens. By the aid of the microscope it is observed that these individual grains are now altered to quartz, epidote, chlorite, actinolite and similar secondary products in varying degrees. Many grains have therefore entirely lost their original characters, but in most cases it is probable that the original form of the grain is fairly well preserved. Many grains show all the characters of a fine-grained diabase. These were fragments broken from adjacent rocks. Others show flowage and devitrification indicating a more glassy nature. While still others retain nothing of their original character and seem to have invited rapid and complete alteration to the obliteration of everything except external form. These are now most commonly represented by quartz grains penetrated by actinolite needles, or by epidote, or a mixture of epidote and quartz, or by epidote and


East L.
16
17
20
21
R. 18 W.
R. 19 W.
Dre
Trout mere
28
St. Croix River
Osceola
Keweenaw
Diabase
Terraces.
Alluvium.

quartz and chlorite. The finer material of the tuff is at the same time the more angular. It is altered chiefly to epidote and quartz. Large, well rounded grains are in relatively small amount.

This is one of the few localities noted in the geological literature of the Lake Superior district where a well defined tuff derived from volvanic ash occurs. References made to similar accumulations on Michipicotin island by Selwyn,* and at Duluth by Winchell and Grant† are the only descriptions with which the author is acquainted.

Alteration Processes and Products. Quartz, epidote, chlorite, calcite, orthoclase, hematite, magnetite, hornblende, actinolite and copper are the usual secondary minerals of the diabase. Quartz, epidote and chlorite are everywhere abundant. Those portions of the rock which have altered largely to quartz and epidote are the most firm and indestructible varieties. Many small veins are filled with a fine grained mixture of these two minerals which sometimes carry native copper in considerable amount. Quartz veins and cavities filled, or partially filled, with quartz are common. Epidote is sometimes well crystallized in these cavities in small individuals. In many instances secondary orthoclase is associated with these occurrences. A fibrous quartz vein filling is also found, probably a pseudomorph after other secondary minerals. The quartz fillings of amygdules are in certain localities highly colored by ferric oxide distributed throughout the quartz grains in beautiful dendritic aggregates. Many amygdules are wholly filled with chlorite. In others epidote is associated with the chlorite in varying proportions to a complete replacement. The amount of secondary quartz is also found considerably more abundant with the epidote than with the chlorite, and in places it is a substitute for both of these minerals. Chlorite fills the greater number of the smaller pseudo-amygdules and is the common secondary product derived from plagioclase and augite. Calcite occurs in amygdules and is sparingly distributed through the diabase of several localities. Magnetite and hematite are abundant secondary products. The rock takes on a dense black color due to their presence, while

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*Science, vol. I, 1893, pp. 11, 221.

†Amer. Geol., vol. XVIII, Oct. 1896, pp. 211-213.

thin sections show that the cleavage and fracture planes of the primary minerals as well as the interstices between them are more or less completely filled with these alteration products. No titanic acid is discovered in the rock. The small plagioclases are the only original constituents whose outline and original character are even partially preserved where magnetite segregation has been most energetic. In the fresher portions of the diabase the plagioclases are clear and comparatively unaltered: in the more advanced stages of alteration, quartz and epidote pseudomorphs preserve the original crystal form in considerable perfection. The staining due to ferric oxide is common to all phases of these rocks. Hornblende is not abundant. One of its most interesting developments is a fibrous vein-filling which in turn is being replaced by secondary quartz. There occurs sparingly distributed in certain altered phases of the diabase, and quite abundantly developed in the accompanying fragmental beds, a fibrous secondary mineral identified as actinolite. It occurs most commonly piercing the quartz grains which are abundant in these altered phases.

Summary. As a summary of the observations made on the alteration tendencies of these rocks, the following statements can be made:

First.—There is an alteration towards quartz and epidote leading to a most indestructible rock. The upper zone of each flow is more subject to this alteration than any other portion, although the inclination to this change is not confined to any particular part of the flow. The rock always assumes a yellowish green color in this stage.

Second.—There is an alteration toward a highly ferruginous rock in which the usual secondary minerals are present, but in which secondary hematite and magnetite are accumulated in great abundance along all boundaries and fractures of the original minerals. The color of the rock becomes then a dense black.

Third.—There is an alteration toward a kaolinized earthy mass in which the only minerals determinable are quartz and kaolin and an iron oxide with more rarely copper carbonate stains. This phase is almost wholly confined to the basal conglomerates in which the conditions for disintegration and the

removal of soluble substances are especially favorable. An intermediate stage common in varying degrees to each line of alteration is that of chloritization. There seems to be no variety of this rock wholly free from this last named product.

CHAPTER III. *Minerals.*

Gold. An assay of the pyritiferous shales at Taylor's Falls shows traces of gold, but beyond this no evidence of the precious metal was found in any of the rocks of this area.

Copper. Native copper occurs in small quantity in the epidotic portions of the diabase flows. A thin section cut from a rock specimen taken from an epidote vein, Sec. 1, T. 34 N., R. 19 W., shows numerous grains of copper scattered throughout the slide. The matrix is a finely crystalline intermixture of secondary quartz and epidote. Copper is also found occasionally in the glacial drift.

Pyrite. This mineral occurs sparingly in the igneous rocks. It is most readily obtained in the railroad cut at Taylor's Falls and at a similar cut on the "Soo" road, two miles north of Dresser Junction. Pyrite occurs in great abundance, however, in the Lower Dresbach shales. The finest specimens were obtained in the small ravine below the carding mill in Taylor's Falls. In portions of the shale at this place small rounded concretions of secondary pyrite the size of a pin head constitute fully one-fourth of the bulk of the rock. Forms of brachiopod shells are also preserved by the pyrite. The plentiful yellow and white efflorescences formed on the exposed surfaces of these shales are no doubt chiefly the result of decomposition of the pyrite.

Quartz. This mineral is crystallized sparingly in the larger cavities of the diabase. It occurs as a coarsely crystalline filling in amygdules and in veins. In the form of more or less rounded grains it constitutes the bulk of the sedimentary strata of the area. A cryptocrystalline variety is noted in certain of the sections of volcanic ash.

Magnetite. Primary and secondary magnetite is abundant in most varieties of the igneous rocks of the area. As a primary constituent it occurs in grains of more or less regular outline imbedded in the diabase. As a secondary constituent it occurs in irregular aggregates and branching spear-like

forms and dense masses in badly decayed portions of the rock from certain localities. In some instances this secondary magnetite constitutes almost a perfect outline of an original mineral constituent, and usually accumulates along the margins or in the crevices of such decaying minerals.

Hematite. Ferric oxide is abundant as a staining substance in the sandstones and conglomerates. In many places the veining produced by the accumulation of this oxide in the sandstones produces branching figures of surprising complexity. In other places accumulations are more abundant and exhibit all the characters of hematite ore. Hematite is also formed as a fissure filling in the diabase. And the quartz of these rocks is highly colored by especially beautiful dendritic crystallizations. The rusty brown color noticeable on decaying surfaces of the mottled diabase is ferric oxide. The calcareous shales are so highly charged with it as to present a brown red color on a fresh fracture. But in spite of its abundance and wide distribution, there is no considerable segregation at any single point.

Calcite. Within cavities in the conglomerate at St. Croix Falls there are developed numerous well-formed calcite crystals. They are chiefly of the nail head variety, although other forms also occur. A similar crystallization of calcium carbonate occurs in the conglomerate at Taylor's Falls, but the crystals are not so well-formed nor so abundant as at the other locality. Crystalline calcite occurs sparingly in the diabase.

Travertine. This variety is deposited in very compact and well banded masses in the larger cavities and caverns of the Dresbach formation along the river bluffs.

Dolomite. Small crystals of dolomite associated with calcite are abundant in the conglomerate at Taylor's Falls. Certain compact portions of the exposure exhibit a crystalline phase in which the chief constituent is dolomitic in composition.

Malachite. Malachite is seen in many places near a contact of the sandstone and diabase as a green, earthy coating upon quartz grains or in cavities among the boulders of conglomeratic phases of the rock. It is especially noticeable at the Taylor's Falls conglomerate exposure. Oxide of iron containing copper and coated with malachite was secured from Sec. 1, T. 33 N., R. 19 W., from the sandstone.

Azurite. The blue carbonate has been noted in association with malachite and dolomite. Other copper minerals have been reported from this locality but have not been encountered during this investigation, and visits to the sites of old mines have not usually shown any traces of the minerals for which they were worked.

Orthoclase. Secondary feldspar is rather well developed in cavities of the rocks where there has been considerable alteration. It is a flesh red mineral altering readily to quartz and frequently exhibiting crystal outlines. It is associated chiefly with quartz and epidote.

Labradorite. Both original and secondary feldspars are present in the diabase rocks. The original representatives of this group all belong to the plagioclase division near "labradorite." There is no essential difference between the large phenocrysts of the porphyritic phases and the smaller individuals of the second generation in the ground mass. All the feldspars show more or less alteration to kaolin, chlorite, epidote and quartz, and in many cases nothing remains but the outlines of these pseudomorphs to indicate the character and position of the original constituent.

Augite. This mineral is prominent in the fresh eruptive rock. It is especially well-developed in the lustre-mottled variety, where crystals of this mineral serve as the hosts for numerous plagioclases giving a typical ophitic structure.

Hornblende. Hornblende is not common. It occurs however, as a secondary mineral in a few sections. The specimens already noted indicating a replacement of fibrous hornblende by quartz are the most interesting.

Actinolite. In many sections cut from the more highly altered rocks, and especially from those carrying a considerable amount of secondary quartz, is a fine fibrous mineral which is believed to be actinolite. Its fine, hair-like fibers, usually crystallized in radiating bundles, penetrate the quartz grains in great profusion. This mineral has been noted chiefly in the bed of volcanic tuff and in the brick-red blotches occurring in the diabase at the elbow of the river on the Wisconsin side. This is supposed to be the mineral referred to by Kloos and Streng as apatite needles.

Muscovite. A light colored mica identified as muscovite

occurs in the Franconia sandstone and in the lowest bed of the Dresbach shales. It appears as minute glistening scales abundantly among the other mineral constituents of this formation.

Biotite. This mica is developed occasionally as a secondary product in the alteration of the diabase.

Epidote. Next to chlorite the most abundant secondary mineral is epidote. It is the yellowish green variety and gives those portions of the rock in which it is a prominent constituent a characteristic yellowish green color. Many amygdules are filled with this mineral. and in some them it is quite perfectly crystallized. Quartz and epidote are contemporaneously developed. Needles of epidote penetrating the clear grains of quartz are frequently seen. Epidote is apparently of later development than chlorite. although all the secondary products are at times simultaneously produced.

Olivine. No olivine has yet been observed in any portion of this rock. Certain apparently pseudomorphous developments of secondary products may possibly indicate the original presence of this mineral. There is. in the first place, a segregation of secondary magnetite forming the outline of a well-defined crystal form closely resembling the usual occurrence of olivine. There is also a canal-like structure sometimes present in the areas of chlorite which may indicate that it is a pseudomorph after the usual serpentinous alteration product from olivine.

Chlorite. The mineral identified as chlorite is an amorphous or granular or sometimes fibrous substance which has a uniformly deep green or bluish color. It has a hardness of 2; it occurs in great abundance in all phases of the diabase as a secondary product. replacing portions of the original minerals and filling cavities and interstices between them. The universal presence of this substance gives all varieties of the rock a greenish cast. It seems to be the earliest secondary mineral. In one of the sections a decomposing feldspar crystal is seen changed first to chlorite at a considerable distance from the lines of fracture, while after it in a narrow zone following the original fracture are developed quartz and epidote in small amounts. Those localities in which the rocks are most free from chlorite display the most highly epidotic zones.

Glauconite. An earthy granular bright green mineral occurs abundantly in the Dresbach formations. It is recognized as glauconite and is the same mineral that is so abundant in the St. Lawrence formation of many localities.*

Kaolin. This mineral is present in small quantity as an accompaniment of the process of alteration. A few specimens, however, have been obtained in which kaolin is the chief resultant of decay. This particular line of alteration seems to have been of limited extent, as suggested in a previous paragraph, and is most noticeable in the conglomerates of the Dresbach formation.

Apatite. Phosphoric acid is abundant in the lower sedimentary strata of this area. The Lingulepis shells give strong tests for this compound and in the green-sand bed numberless microscopic apatite crystals have been developed as a secondary mineral constituent. The phosphoric acid reaction is readily obtained from the Obolella (green-sand) bed and also from the Lingulepis (calcareous) shale. Although these microscopic crystals are very perfectly and abundantly developed, no individuals of larger size have yet been observed.

Sulphates. The efflorescence formed on the exposed pyritiferous Dresbach shales at the carding mill, Taylor's Falls, has proven quite complex in its composition. The results of an analysis made by Mr. H. A. Webber, a student in the University of Minnesota, is as follows:

SiO_2	12.946	per cent.
Fe_2O_3	22.828	" "
Al_2O_3	4.141	" "
K_2O	1.844	" "
Na_2O	4.659	" "
CaO	2.210	" "
SO_3	32.500	" "
H_2O	17.840	" "
Organic matter	traces	
Total	98.968	per cent.

This analysis is similar in complexity and general range to voltaite (Dana, p. 927), but it is not identical with any known mineral. It is apparently a mixed substance. The most puz-

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*Magnesian Series of the Northwestern States. Bull. Geol. Soc. of America, vol. V, 1895, p. 172.

zling parts of the analysis are: SiO_2—12.946 per cent and H_2O—17.848 per cent. Silica is high and apparently out of place, while H_2O is low for the sulphates. This substance forms abundantly on the exposed shales as greenish yellow rather compact and somewhat globular masses out of the water which is constantly dripping from the lower beds. Whenever these masses become detached or are subjected to evaporation the efflorescence is noticeably different in character. It is white and porous or frost-like, and presents the usual appearance of the sulphates formed upon exposed marcasite nodules. A bitter taste to the shales at the contact opposite St. Croix Falls was noted by the Wisconsin geologists[*] and ascribed to the formation of sulphates. A complete chemical analysis of the white substance has not been made.

Explanation of Plate XII.

Fig. 1. *Section of Volcanic Tuff.*

The figure is from a microphotograph of a section of the volcanic tuff from Taylor's Falls. Diabasic characters are shown by the darker grains in the figure, and one fragment especially at the right side exhibits a coarser texture than is usual. Several grains near the lower margin of the field are devitrified glasses. In grains of this character flowage is sometimes prominent. The light colored fragments throughout the field are now chiefly quartz. But these almost all show their secondary character by the penetration of actinolite needles which project in beautiful clusters. Finer fragments of a more angular outline lie between the larger grains.

Fig. 2. *The St. Lawrence Shales.*

The figure is reproduced from a photograph of a hand specimen obtained at Osceola Falls. The darker portions of the figure represent quartz sand; the light wavy threads and bands are greenish clay shale. A study of this specimen and a comparison with others of different localities, especially those representing phases of the dolomites, and also a series of chemical tests, completed since writing the paragraph referring to this figure in the text, altogether have led me to ascribe not a little of the irregularity of banding in the shales to the removal of soluble constituents subsequent to their original deposition. The St. Lawrence formation in some localities is a dolomite. A theory of the origin of dolomites as maintained by Hall and Sardeson in their paper on "The Magnesian Series of the Northwestern States" (loc. cit.), argues the removal of calcium carbonate from rocks at a greater rate than magnesian carbonate. The result is a limestone growing by continuous

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[*] Geology of Wisconsin, vol. III, 1880, p. 418.

reduction into a more arenaceous or argillaceous and a more highly dolomitic rock, and at the same time one which is more irregular in its bedding lines. In the true dolomites the shale and sand constituents have been evidently of small amount. But in strata where these two constituents are prominent, the process would doubtless result in a distortion of the sedimentary banding similar to that of the figure. This may become, as in this case, the most noticeable distinguishing feature of the rock.

RESIDUAL CONCENTRATION BY WEATHERING AS A MODE OF GENESIS OF IRON ORES.

By James P. Kimball, New York.

In descriptions of important secondary deposits of sub-specular iron ores on the south coast of Cuba in the year 1884,* mention was made of other numerous interesting but commercially unimportant, ferriferous products different in type and likewise secondary. These were characterized as concentrations of ferric and magnetic oxides upon outlying surfaces of dioritic dykes, and also developed to some extent within a great mantle or overflow of diorite. Involved within the same overflow are enormous isolated masses of elevated and disrupted coralline rock, some of which in stated circumstances have completely given way to replacement by hematite and martite. Further illustrations of both types of deposits have also been given by the present writer in a recent number of The American Geologist† with reference to associated occurrences on islands of British Columbia. Incidental mention was made in the same place to similar occurrences in culminating regions of the Cascade range in Washington.

Numberless dykes in the foothills of the Sierra Mæstra in Cuba, alike in age and original character, have undergone no such superficial alteration as above referred to, or, at least, preserve no evidence of the kind. That such superficial concentrations of oxides of iron are not due to original magmatic differentiation, on the Soret principle, is clear from the fact that eroded tops of intrusive masses and dykes are apt to pre-

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*Am. Jour. Sci., XXVIII, 416; Trans. Am. Inst. Min. Eng., XIII, 613.

†Vid. Vol. XX, July, 1897.

sent the greater display of ferriferous products. Their development is limited to exposed surfaces. When otherwise than a mere speculum, the oxide is characterized by prismatic cleavage. Both detritus and float are then particularly rich. Dykes in which no prismatic cleavage is pronounced exhibit as a rule no more than a coating or specular surface of ferric oxide. This holds true with regard to the more expansive intrusions. When presented in outliers distinct from the overflow some of these are of imposing aspect, bearing semblance to fine bodies of ore. The sharp ringing sound from a blow with the hammer serves to distinguish such masses, as well as any form of their detritus, including even an excellent type of ore of like origin, abundantly afforded in places as float.

From the fact that the iron ores classified in my original descriptions as concentrations are essentially superficial, it was argued on general grounds that little or no economic value could attach to them. So deceptive in appearance, however, were some of these occurrences in an unbroken state in the year 1884 that several of them had been located by denouncement, and the critical attention of geologists and capitalists confidently invited with a view to development as ore deposits.

Reference is here made to a subordinate and worthless type of ferriferous developments rather than to the characteristic class for which the region is renowned, because it serves the present purpose of comparison with somewhat analogous occurrences which have proved even more deceptive in appearance. Both occurrences are, nevertheless, significant of one mode of genesis or differentiation of iron ores, namely, by residual concentration of iron oxides as a result of weathering action.

The second instance referred to is a remarkable differential development of ferric and magnetic oxides from an amorphous basic aggregate in the state of Washington on Cle Elum river, one of the tributaries of the Yakima. This fine mountain stream, which expands into two lakes of the same name, distinguished as Upper and Lower, penetrates the more mountainous parts of its course in a deep gorge several miles long. Mountains on either side rise to elevations of several thousand feet. The Cascade range on the west presents tow-

ering escarpments rising from the river canon. On the opposite side foothills of the same range fall off toward the valley of the Columbia.

At the time of my visit to the region, in the month of September, 1890, some eighteen contiguous mining claims had been located, together forming a loop, and covering the bottom lands and both mountain sides. The whole stretch of locations compassed what was concluded to be remnants of a faulted boss or dome of a stratiform ferriferous series. By subsidence of the arch the medial portion overspreads the narrow valley bottom wherever not obliterated by erosion. Uneroded parts in minor undulations traverse low hillocks. Hence gentle quaquaversal dips and small saucer-like basins. Steep retreating dips of the same series enter the mountains on either side beyond the planes of fault at different elevations, namely, at 4,675 feet on the east and about 1,000 feet lower on the opposite side. From the greater part of the area of the bottom lands the ferriferous beds have been eroded. Even on the circling line of mineral locations corresponding to an outer margin of the subsided arch their preservation is only partial. The present river channel follows the line of the western fault.

Affected as they are by unequal erosion and somewhat variable in section, the beds in question present a total thickness of from six to eighteen feet. They constitute three divisions of an amorphous aggregate. This series is underlain by crystalline pyroxene and surmounted by micaceous sandstone passing into conglomerate, both conformable and of metamorphic type.

The notable occurrence of iron ore, properly so discriminated, is at the base of the series of ferriferous, or, rather, ferruginous, beds. In quality and thickness this is far from uniform. Its development is confined to wet places and exposed ledges.

In circumstances thus favorable to atmospheric oxidation and percolation of water, magnetite, martite, hematite and limonite have been exfoliated as an insoluble residuum from decomposition of the basic aggregate. These mixed products have a foliated structure. The separate folia serve to distinguish progressive exfoliation of iron oxide. Thus siliceous residuums separate lustrous folia of chromiferous magnetite,

and, in the case of more thoroughly weathered material. more or less hydrated hematite likewise chromiferous. The thickness of the deposit in this particular relation varies from two to eighteen inches. Just beneath developments of this description the basal pyroxene is, to the depth of a few inches. commonly decomposed into a soft chloritic clay.

In places, where local topography has been favorable to weathering action this ferriferous exfoliation graduates upward into an impure sub-specular product, a mixture of ferric and magnetic oxides characterized by a remarkable prismatic cleavage which seems wholly incidental to the partial or incipient alteration. Though possessing a low specific gravity and affording a green streak and powder, this product is of a dull sub-metallic lustre on all cleavage faces even to the minutest mechanical sub-division. Natural surfaces of outliers of this base material, such as are developed by a sort of potential cleavage, are commonly veneered with ferric oxide of submetallic lustre.

In extremely favored spots, as on "Magnetic Summit," so-called, the peak of Emerson, or East Mt., the same division at shallow depths is more thoroughly altered into a dense sub-specular product of high specific gravity. Similar material likewise unequally developed on a small scale is sometimes noticed amongst the gleanings at the several excavations in the valley. The quantity, however, is commercially insignificant, and the quality of the best indifferent.

At several of the explorations no development of distinctly ferriferous products is observed, especially in well drained hillocks. At others specimens of rich iron ore, chiefly from the base of the series, can be gleaned. On the more northerly locations, known as the Duke and the Iron Bluff, in the valley bottom, no development of ore has taken place, the black lustrous surface of the outliers alone affording semblance to iron ore. The miscellaneous character of the products submitted by the explorers for analysis is proof of the indiscrimination with which they had collectively been regarded. The bulk of the whole material had, indeed, been mistaken for iron ore, not only by local miners unfamiliar with iron ores, but also in one instance by a professional observer specially sent out from London.

The third or upper division is characterized by a submetallic lustre and by prismatic cleavage—both evidently developed by weathering. Although apparently of the same mineral composition as the two lower beds, it is in places largely made up of pebbly or spherulitic differentiations, the origin of which is an interesting object of inquiry thus far unaided by the microscope. Interposed between aphanitic layers and an overlying siliceous conglomerate, this bed, macroscopically at least, has the casual appearance of coarse augitic psammite. Between a clastic origin and a concretionary origin of the spherulitic contents there lies a doubt. These have become pronounced, if, indeed, they have not actually been developed, by weathering action, as manifested by partial or complete replacement of the original material with anhydrous oxides of iron. In comparatively unaltered rock, as on the Monarch location, the only feature in obvious relation to such occurrences is a mottled fracture suggestive of unpronounced or incipient concretionary structure. In some parts of this bed, as on the Boss and Iron Monster locations, an iron ore of tolerable quality is developed by more or less complete conversion of the spherulites into ferric oxide. Isolated and protuberant examples of these products bear resemblance to terebratuloid forms. The mineral alteration which they have undergone is of the same kind as that which has taken place on the surface of exposed ledges and on cleavage surfaces. While it is true that the third bed which, as the most pronounced in character must be regarded as the physical type of the thin series, is not without features in common with a clastic tuff of volcanic origin, the above facts, taken along with certain negative evidence, point, as I conclude, to a metamorphic origin.

Every gradation in tenor of iron oxides from unaltered to highly metalliferous material is presented by all of the beds—sometimes within a very narrow compass. Material from all of the beds exhibits polarity. Fragments from the middle bed on Iron Mt., where the attitude of the series is nearly vertical, act as powerful loadstones. Even the unaltered greenish augitic material, charged with minute grains of magnetite, is not without decided effect on the magnetic needle. The presence of lime, as shown by analysis, is doubtless an important agent in the transformation above described. As in most

ferriferous developments from serpentine, the richer products are also shown to be chromiferous.

Numerous commercial analyses of the material above described had been made at the instance of the owners. Notwithstanding a lack of full description of the samples analyzed, the significance of these incomplete analyses, taken together, is plain.

Samples collected at six different points by an English engineer, and by him claimed to represent a seam or belt fifteen to twenty feet in thickness, afforded, upon analysis by Dr. Edward Riley, of London, a mean percentage of iron as high as 51.110, and of silica as low as 7.410.

That these samples, while perhaps approximately representing concentrations as above described, failed to represent anything like the average composition of the whole formation is sufficiently clear, beyond a doubt, after careful discrimination.

A series of seventeen partial analyses by Prof. James A. Dodge, of the University of Minnesota, however, may be assumed to represent several of the more ferriferous types of material. Of the number of samples furnished to Prof. Dodge by interested parties, nine were products ranging from 49 to 63 per cent. in iron. The rest of the analyses, though incomplete, indicate clearly enough the character of basic aluminous silicates. The following are the analyses referred to:

Locations.	Metallic. Iron.	Alumina.	Silica.	Phosphorus.	Sulphur.	
Dudley (hematite)	63.05	......	......	trace	0.04	....
Emerson (centre)	57.51	2.39	11.07	0.06	......	ChO & Mn
Emerson (top)	55.84	2.61	13.32	0.05	none	do
Beverly (hematite) (4.68 undet.)	60.95	0.84	6.07	0.01	none	ChO, 1.33
Magnet	56.79	2.26	9.49	0.02	"	ChO
Stronghold	52.31	4.72	14.32	0.03	"	"
Nigger baby (limonite)	52.99	......	......	0.25	"	....
Clayton (magnetite)	49.44	......	......	0.18	......	....
Boyle (hematite)	51.39	......	......	trace	0.04	....
Nelson	42.85	6.01	24.98	0.16	0.02	CaO, Mn
Swak	22.37	15.65	43.64	0.03	0.01	"
Haskell	22.71	12.17	47.09	0.11	0.02	"
Mack	24.36	7.95	47.40	0.09	none	CrO
Cle Elum lake	15.36	7.71	37.33	0.03	0.05	CaO
Iron Yankee	42.38	6.19	20.89	0.01	0.01	ChO
West Gulch (magnetic)	40.74	......	......	0.15	none	....
Mother Hubbard (magnetic)	39.29	......	......	0.01	"	....

For lack of considerable development of ores of a high class, the mineral locations here briefly described are of no economic importance. The false estimation in which they had been held arose from failure to distinguish between the several kinds of material selected for analysis with due reference to their relative quantitative development. As an example of one mode of genesis of iron ores, however, the occurrences on the Cle Elum are not without significance.

Specimens collected by myself to represent extreme types of the two kinds of material, the one altered (I) and the other unaltered(II), both from the Boss location, have been analyzed by Mr. Cabell Whitehead, Chemist of the Bureau of the Mint. The analyses are as follows:

	I	II
Ferric Oxide	82.56	50.26
Ferrous oxide	1.24	0.69
Alumina	4.08	23.70
Chromic oxide	5.20	Not determined.
Lime	0.28	1.27
Magnesia	1.01	1.02
Manganous oxide	0.30	0.43
Oxide of Nickel	0.68	Not determined.
Silica	3.10	14.40
Water	1.53	Not determined.
	99.98	
Metallic iron	58.77	35.16

According to Mr. Whitehead's analysis the comparatively unaltered product (II) is remarkable for its high tenor of ferric oxide in relation to the low percentage of ferrous oxide. The figures point, of course, to epigenesis of the higher from the lower oxide in spite of the green streak and powder of this product.

The occurrences above noted clearly indicate, as it seems to me, the differentiation of iron oxides from an amorphous basic aggregate through weathering action on natural surfaces by residual concentration incidental to isolation and waste of earthy residuums. Development of prismatic cleavage and exfoliation of the same oxides on cleavage planes, even to the minutest sub-division, are incidental phenomena. That the oxidation of ferrous oxide in unisilicates to the higher oxide through meteoric influences in so dense an aggregate is thus limited, except in wet places, is not difficult to explain. The fixation of ferric oxide is probably not disconnected from

initial replacement of calcic carbonate through ferrous carbonate—both products of the splitting up of basic silicates. the original components of which were not in stochiometric proportions. The last inference may be drawn from the amorphous condition of the ferriferous beds as well as from analyses. The only evidence of any other kind of differentiation is occasional segregation of calcite.

In the present example the transformation is obvious. Equally obvious, of course, it would not be had its progress involved the whole formation, or even uniformly a single division. In the bearing of this example on differentiation and concentration of ferriferous products from basic and somewhat magnetic aggregates, it is uncommonly instructive. Similar differentiation from eruptive basic magmas in Cuba previously instanced as a product likewise of weathering action, affords a further illustration of a common mode of genesis of iron ores from basic material.

It is natural to infer that superficial and even interstitial concentration of stable magnetite incidental to hydro-chemical rearrangement and leaching of basic rock, of which this mineral is a component, may be largely, if not wholly, residual. Apart from such a mode of occurrence as distinguished by special paragenesis, its presence in concrete form in non-magnetic rocks, in numerous cases instanced by the writer in previous pages of THE AMERICAN GEOLOGIST, is through stochiometrical transformation of ferric hydrate at ordinary temperatures. Transformation of this kind by gradation proves to be among the more common microscopic manifestations of epigenesis of basic crystallines, attended with loss of basicity. Diminished basicity seems invariably, so far as I have observed, and as I have instanced in numerous descriptions, to characterize and differentiate regional parts of rocks marginal to concentrations of anhydrous iron oxides, and as particularly witnessed in development of secondary siliceous, or residual products like chlorite, epidote, garnet and jaspers from gabbro, diorite, diabase, etc. Superficial, unlike interstitial, concentrations in basic rocks seldom, if ever, appear of economic importance. Far more important products are those derived from essentially calcareous paragenesis when iron salts, locally generated and entering into passing solu-

tions, have yielded to the stronger base. While chemical action is here only in a limited sense superficial, progression is from without inward. Replacement of calcareous material, like limestones, marbles and coralline rock, with ferrous salts, is then effected, whence spontaneous development of ferric products on receding surfaces. Among the several examples of advanced or advancing replacement of this kind which I have had opportunities to study, are several where it is complete, and others again where it is only partial. In the latter class the mode of occurrence is always the more obvious. In every case the degree of purity of the ultimate ferriferous products depends, of course, on relative degree of siliceous admixtures in the parent material.

The common association of the higher ferric oxides in more or less concrete form, as on Texada and Vancouver islands, with epidotic products from epigenesis of hornblendic aggregates, in which products the iron base is present as ferric oxide, points to ultimate or residual concentration of the same oxide from the secondary product by progressive epigenesis, and perhaps also in some ratio of original distribution of ferrous oxide in the parent material. Beyond some ratio limit of this kind still further development of ferriferous products points again to extraneous or diffuse sources of ferrous solutions, and likewise to circulation of alkaline carbonates evolved from silicates.

The phenomena above described, in common with others of the same class previously illustrated,* notwithstanding widely varying paragenesis and environment, are, in a word, all incidental to fixation of stable iron oxides from penetrating solutions of ferrous salts by progressive oxidation, following as a final result from primary double decomposition with alkaline carbonates by processes more or less regenerative. In the memoir first cited below the cyclus referred to has been fully discussed from a chemical point of view.

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*Am. Jour. Sci., XLII, 1891, 231; XXVIII, 1884, 416.
Am. Geologist, VIII, 1891, 352; XIX, July, 1897.
Trans. Am. Inst. Min. Eng., XIII, 1884, 613.

OSCILLATIONS OF LEVEL OF THE PACIFIC COAST OF THE UNITED STATES.

By WILLIAM P. BLAKE, Tucson, Arizona.

The oscillations of level of the California coast have of late years been ably discussed by Lawson,* Ransome,† Davidson, Le Conte and others, and recently in this journal by Fairbanks.‡

In these discussions the significance of the Ocoya Creek formation does not appear to have received the recognition it merits.

Lying at the western base of the Sierra Nevada in undisturbed horizontal strata of marine origin of wide extent and at an altitude of from 700 to 1,500 feet above the sea, this formation records an epirogenic movement in strong contrast with the orogenic uplifts to which the initial topography of the Coast ranges is due. The beds consist, generally, of sandy sediments accumulated during a period of subsidence, and in comparatively shallow water. But they contain evidences of considerable volcanic activity, such as beds of pumice and even fragments of charcoal showing the prevalence of forest fires, due, probably, to incursion of lava in the ancient forests of the Sierra.

The marine remains consist of numerous genera and species of Mullusca piled together in a littoral accumulation at the base of the hills, and now some 700 feet above tide-water, while from the tops of the hills which rise some hundreds of feet higher the teeth of sharks and bones of cetaceans are strewn upon the mesa as upon the ocean floor. The evidence of recent epirogenic uplift appears to be conclusive.

The exact altitudes of the ancient shell beds and of the tops of the hills need to be more carefully determined than was possible at the date of the reconnoissance in 1853, but it would appear from those observations that the upper beds are now at least 1,500 feet above tide. It is also desirable to have a re-

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*The Post-Pliocene Diastrophism of the Coast of Southern California, by Andrew C. Lawson, Univ. of Cal. Bull. of the Dept. of Geology, I, No. 4, Dec., 1893. Also The Geomorphogeny of the Coast of Southern California, Ibid, No. 8, Nov. 1894.

†The Great Valley of California—A Criticism of the Theory of Isostasy, by F. Leslie Ransome, Ibid, No. 14, May, 1896.

‡Oscillation of the Coast of California during the Pliocene and Pleistocene, by Harold W. Fairbanks, Oct. 1897, No. 4, p. 213.

vision of the question of the age of the formation, considered by Conrad to be Miocene. This opinion was formed upon the genera and species represented by the drawings made by me upon the spot from the casts of the fossils.* In many cases the specific character of some of the common genera, *Cardium*, *Arca*, *Selen*, *Dosenia*, *Venus*, and *Cytherea*, could not be made out. The remains of cetaceans were found by me at a second visit many years after the publication of the results of the collection made in 1853. The whole aspect of the hills is more modern and recent than of any well-recognized Miocene of the western coast. But whether Miocene or Pliocene the formation records a comparatively recent uplift of 1,500 feet or more, after a subsidence of an equal amount and sufficient to give the Pacific ocean free access to the base of the Sierra Nevada and to make a chain of islands of the Coast mountains.

[**European and American Glacial Geology Compared. II.**]

VALLEY MORAINES AND DRUMLINS IN THE ENGLISH LAKE DISTRICT.

By WARREN UPHAM, St. Paul, Minn.

From Llanberis we returned June 14th (1897) to Carnarvon, and the next day to Chester, continuing thence northeast and east through Manchester and Huddersfield to Leeds. This railway passes in a tunnel about two miles long through the axial part of the south to north highland belt of the Pennine Chain, which is continuous along a distance of nearly 150 miles through northern England.

Under the guidance of Prof. Percy F. Kendall and Mr. Arthur R. Dwerryhouse, of the Yorkshire College, Leeds, I much enjoyed an excursion north nearly twenty miles to Harrogate and the Nidd valley at Knaresborough and westward.

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*A full description of the Ocoya Creek beds and of the fossils may be found in my "Report of a Geological Reconnoissance in California." 4 to. 1853. pp. 164-173. Also, in Vol. V, "Pacific Railroad Surveys."

In this connection it is well to note a strange jumble of errors in a foot note to Mr. Lawson's paper on "The Post-Pliocene Diastrophism of the Coast of Southern California." Bull. Univ. Cal. Dept. Geol. p. 119. No Miocene fossils, or others, were found by me at San Diego, or were handed to me there. The basis of the reference is probably an echo of the old attempt of Prof. Gabb and the California Survey to discredit my discovery of the Téjon Eocene.

going from an unglaciated to a glaciated area, observing marginal till and kame deposits, and noting glacial changes in the course of the river Nidd.

Leaving Leeds early in the morning of June 17th, our route was west and north through Hellifield and Kirkby Stephen to Appleby, there delaying about three hours for connection with a train to Penrith and Keswick. The delay permitted me to take a short excursion to the east and north, seeing some of the drumlins, 40 to 60 feet high, along this part of the river Eden, in a district well described, as to its glacial geology, by Mr. J. G. Goodchild.* Looking northward from Appleby, we saw snow of the previous day's storm on the top of Cross Fell, the culminating point of the Pennine Chain, 2,930 feet above the sea; and looking west, beyond a finely cultivated lowland, we saw the group of sharp-peaked mountains which occupy the English Lake District, 20 to 40 miles distant.

In Keswick, a town of 4,000 people, near the foot of lake Derwentwater, in the midst of the Lake District (also known as Lakeland), surrounded on all sides by beautiful and grand mountains, we spent the week of the Queen's Diamond Jubilee, which was heartily celebrated in every city and town of the realm. On the evening of Tuesday, June 22d, the chief day of the celebration, a great bonfire blazed forth on the summit of Skiddaw; and from that mountain top more than sixty other beacon fires were visible on the mountains and hills of all the surrounding country.

On the preceding Saturday I had ascended Skiddaw, finding glacial striæ in and near the path on the slate bedrock at two places, about 50 and 100 feet above the upper hut, or by estimate 1,950 and 2,000 feet above the sea, bearing, respectively, S. 45° W. and S. 55° W. (as referred to the true meridian, allowing 20° W. variation). The glaciation is doubtless referable to ice flowing down the mountain slope, as no drift foreign to the mountain is found there nor upward to its summit, 3,054 feet above the sea. Snow that had fallen in a storm on Friday lay an inch or two deep on parts of the top; but the cold and snows of that June were quite exceptional, almost unprecedented within the memory of the oldest people.

Tuesday morning I set out to walk from Keswick to Hel-

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*Quart. Jour. Geol. Soc., XXXI (1875), 55-99.

vellyn and Scawfell (two days' journey), but clouds resting low on the mountains forbade the ascent of Helvellyn (3,118 feet). In the Thirlmere and Grasmere valley, through which the road passes, between an eighth and a quarter of a mile south of its highest point, called Dunmail Raise, I found a distinct valley moraine, a knolly transverse ridge of drift, the first of many noted in the great valleys of this mountainous district during my further journey to Scawfell and thence down the Derwent valley to Keswick. This moraine has a hight of about 20 feet, a length of nearly 1,500 feet, extending up the inclosing mountain slopes, and a width of 200 to 300 feet. It consists of till, with many boulders up to five feet in diameter, and a few up to ten feet. A larger moraine of similar till, having nearly the same length, but covering a much wider space with its knolls and hillocks, 30 to 75 feet in hight above the bedrock, crosses this valley a third to a half mile farther south; but a quarter to a third part of each moraine has been swept away by the stream. The crest of the road is noted on the Ordnance map as 783 feet, and these moraines are between 800 and 700 feet above the sea.

Near Grasmere village and lake three drumlins were seen, one 30 feet high being close west of the road about three-fourths of a mile north of the village; another, about 100 feet high, forming the top and greater part of the Butharlip How hill, in the north edge of the village; and the third, about 90 feet high, on the east shore of the lake (206 feet above the sea). Each of these drumlins has the typically oval form, with trend in parallelism with the southwardly declining valley.

Crossing the ridge south of Grasmere, and advancing thence west up the Great Langdale valley, I observed an exceptional depth of drift, perhaps a terminal deposit, on each side of that valley near Elterwater village, one-fourth to three-fourths of a mile northwest of the lake or tarn of this name. Along the next three miles west the valley bottom is an alluvial plain a fourth to a third of a mile wide, with a very gentle descent eastward, in part probably marking the site of a temporary and shallow postglacial lake.

Farther west, as I advanced up the narrowing Mickleden valley, a very noteworthy display of valley moraines was encountered from one mile to two miles beyond the Old Dungeon

Gill hotel. These are crossed by the path to Scawfell, being at the southwest base of the craggy Langdale Pikes (peaks). In the valley, between 400 and 600 feet above the sea, eight or ten clearly defined transverse moraines of bouldery till are accumulated in small ridges and hillocks from 10 or 20 feet to 50 or 60 feet high. Above the more northwestern of these moraines, a large deposit of till is spread upon the southwest side of the valley, forming the surface of the Green Tongue, a spur of Bow Fell, to a hight of 500 feet above the stream. This glacial drift is covered with grass, and its bright green is in marked contrast with the dark gray rock and talus slopes of other parts of the mountain sides inclosing the valley.

In descending to Keswick from the rugged crest of Scawfell Pike (3,210 feet), an equally interesting series of small moraines is seen in the Derwent valley from the mouth of the Sty Head Gill to Longthwaite church and hamlet. Along this distance of two miles, with descent of the river from 500 to 300 feet, approximately, above the sea, nine moraines were found, five of small size being in the first half mile before coming to the Seathwaite farm houses; a most remarkable curving moraine, a half mile long, with abundant and large boulders, at the Thornythwaite house, a mile farther down the valley; and three other knolly drift belts crossed within the last quarter of a mile before coming to Longthwaite.

Probably these nine moraines were formed contemporaneously with the similar number in the Mickleden valley, the two series being respectively the records of the receding Scawfell glaciers, during the last stage of the Glacial period, on the north and east sides of this highest mountain mass of the Lake District. Below the Scawfell névé fields by which these glaciers were fed, their lengths, at the time of formation of the lowermost in the series of moraines here noted, were only about three miles on the north and one and a half miles on the east. At nearly the same time the névé areas on Helvellyn and on the great ridge running north from the Langdale Pikes sent confluent glaciers into the southern part of the intervening Thirlmere valley, forming the moraines close south of Dunmail Raise, one and a half to two miles south of lake Thirlmere.

Six drumlins were noted and mapped by me in Keswick

and its vicinity, within a half mile north, northwest, west and south of the town, and drumlinoid slopes of till rest on both the northwest and southeast sides of the isolated rock knob named Castle Head. Other drumlins await mapping within one to two miles farther west and northwest, but none were seen in attentive outlook from our train as we travelled thence to Penrith, Carlisle, Melrose, Edinburgh, Aberdeen and Inverness. Drumlins were afterward found admirably developed, however, in Glasgow and its environs, to be described in the next paper of this series.

The careful field observations and writings of J. Clifton Ward* assure us that the Lake District mountains were a center of glacial outflow during the culmination of the Ice age in Great Britain, turning aside the Scottish ice-sheet and its drift. Mingled with that drift in its continuation eastward are Lakeland boulders, as the very distinct Shap granite, carried over the Pennine Chain, and through its gaps, to the lowlands of Yorkshire. The highest summits of Lakeland probably remained as nunataks when the confluent British ice-sheet attained its greatest extent and depth. Outflowing glacial currents from this district, coalescing with the stronger currents of the surrounding general ice-sheet, seem quite sufficient to account for the diverse directions of transportation of boulders in and around the district without referring some of them to marine flotation of ice, as was supposed by Ward. A great submergence, of which the shell-bearing drift deposits at high levels on Moel Tryfan and in other localities were thought to bear testimony, is not needed for explanation of the transportation of either the shell fragments or the Lakeland boulders.

In North America we have scarcely a similar case of dispersal of boulders outward from a limited area, unless it be in the radial glaciation of the less mountainous but larger tract of Newfoundland, which appears to have been connected only by an isthmus of ice with the main continental ice-sheet. The highest mountains of New England and New York were apparently overtopped by this ice-sheet when it became thick-

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*Q. J. G. S., XXIX (1873), 422-441, with map; XXX (1874), 96-104, with map and sections; XXXI (1875), 152-166, with maps. Compare with J. E. Marr's papers, Q. J. G. S., LI (1895), 35-48, and LII (1896), 12-16, each with figures in the text.

est;* but at the end of the Ice age the Adirondacks and the much larger region of the White and Green mountains, with probably the greater part of Maine, continued ice-covered after the glacial blockade was melted through along the Hudson-Champlain and St. Lawrence valleys.† Still later local glaciers, the last representatives of the departing ice-sheet, comparable with those of the English Lake District, existed in the Green and White mountains, forming in some places admirable series of valley moraines accumulated by ice flowing northerly, in directions opposite to the earlier general glaciation.‡

Our mountains in the glacial drift area are less interesting than those of Great Britain as centers of drift dispersion, because through the greater part of the Glacial period they shared in the general southward ice movement; but they have very significant later valley moraines, which, according to Agassiz, rival the recent recessional moraines of the Rhone glacier. A most inviting field for American glacialists is the more thorough exploration and correlation of these last valley moraines of the White, Green and Adirondack mountains.

SOME METHODS OF DETERMINING THE POSITIVE OR NEGATIVE CHARACTER OF MINERAL PLATES IN CONVERGING POLARIZED LIGHT WITH THE PETROGRAPHICAL MICROSCOPE.

By DR. M. E. WADSWORTH, Houghton, Mich.

For the elementary work in petrography in the Michigan College of Mines the laboratory is furnished with twenty-nine Bausch and Lomb petrographical microscopes specially made for the college, besides numerous other microscopes and petrographical apparatus, making it one of the best equipped laboratories known.

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*Appalachia, V (1889), 291-312 [also in the Am. Geologist, IV, Sept. and Oct., 1889].

†Am. Jour. Sci. (3), XLIX, 1-18, with map, Jan., 1895 [also, more fully in Twenty-third An. Rep., Geol. Survey of Minnesota, for 1894].

‡E. Hitchcock, Geology of Vt., I (1861), 82-87. L. Agassiz, Proc. A. A. A. S., XIX (1870), 161-167 [also in Am. Naturalist, IV, 1870, and Geology of N. H., III, 1878]. C. H. Hitchcock, Geology of N. H., III, 230-250. G. H. Stone, Am. Naturalist, XIV, 299-302, April, 1880.

In giving instruction in the use of the petrographical microscope as a polariscope, I have found a few directions of value to my students,—directions which I do not remember of having ever seen published. Thinking that they might be of some value to some of our readers who are interested in optical mineralogy, these directions are published here. Since by varying the powers, the petrographical microscope can be used with mineral plates of any standard thickness, the directions here given can be used with the ordinary polariscope plates as well as those thinner ones prepared expressly for use with the microscope.

I. UNIAXIAL MINERALS.

When the mineral plate shows the common uniaxial cross in converging light its positive or negative character can be ascertained by means of the gypsum plate or quartz wedge, as well as by the ordinary mica plate.

(*1*) *Use of the Gypsum Plate.*

Examine the mineral plate, which, in converging polarized light, between crossed nicols, shows a dark cross or part of a cross with or without colored rings or arcs. Insert the gypsum plate in the slot in the body of the microscope above the objective. The cross is then resolved into colored hyperbolas. The central portion is red terminated on the ends with yellow and bordered on the side by blue. If the blue that borders the red lies on a line parallel to the axis of least elasticity, the mineral is POSITIVE, but if it lies on opposite sides of this line the mineral is NEGATIVE. The gypsum plate is often more satisfactory in its use than the mica plate for these determinations.

(*2*) *Use of the Quartz Wedge.*

Insert the quartz wedge thin end forward. When the wedge is gradually pushed in the cross resolves itself into colored arcs that cross the field of view from two opposite sides of the field and pass out of sight on the other two sides. These arcs follow each other in succession as the wedge is pushed in. If these colored arcs advance towards the center of a line parallel to the axis of least elasticity the mineral is POSITIVE. But if they march toward the center from opposite sides of that line the mineral is NEGATIVE.

The use of the quartz wedge is less liable to error than either of the preceding; and besides it can be used in many cases where the others give no results.

(a) If the uniaxial plate is cut so that it shows arcs of rings, its positive or negative character can be determined by placing the arcs so a line perpendicular to them shall make an angle of 45° with the cross hairs. By use of the quartz wedge, colored arcs or rings can often be brought into the field, when otherwise none are seen. Push in the quartz wedge with its axis of least elasticity tangent to the arcs. If the rings then move outwards with their convex side forwards, and, in time, a black or partially black arc appears, the mineral is POSITIVE, but if the arcs move with their concave sides forwards the mineral is NEGATIVE.

As a check against any error, turn the wedge over and push it in, so its axis of least elasticity will be perpendicular to the arcs. If then the arcs move with the concave side forward, the mineral is POSITIVE, but if they move with the convex side forwards, and a black or partially black ring or rings show, the mineral is NEGATIVE.

(b) A uniaxial plate cut parallel to the vertical axis can have its positive or negative character shown in converging polarized light as follows: Place the plate at an angle of 45° with the cross hairs so as to show the colored arcs or imperfect hyperbolas. Push in the quartz first with its axis of least elasticity perpendicular to the vertical or optic axis of the plate. If on pushing along the quartz wedge a dark hyperbola is seen to pass over the field the mineral is POSITIVE. Again, push in the quartz wedge with its axis of least elasticity parallel to the vertical axis of the plate. If then a dark hyperbola is seen to traverse the field, the mineral is NEGATIVE.

II. BIAXIAL MINERALS.

In order to render intelligible the directions later given, there is here stated the method published in the text books for determining the positive or negative character of a biaxial mineral plate.

If a line of extinction of a biaxial plate properly cut is placed parallel to one of the cross hairs, it shows a cross with unequal arms; but if the line of extinction makes an angle of

45° with that cross hair, it shows two dark hyperbolas, whose vertices or eyes mark the position of the optic axes. Accompanying the cross and hyperbolas are colored lemniscate figures. Oftentimes the hyperbolas are wanting and only the colored lemniscates can be seen; but by the insertion of the quartz wedge the hyperbolas can frequently be brought into the field.

(a) The positive or negative character of this biaxial plate can then be determined by placing the plate on the stage in such a position that a line joining the hyperbola eyes or bisecting the lemniscates through their longest direction shall form an angle of 45° with the cross hairs. Push in the quartz wedge with its axis of least elasticity parallel to the line joining the hyperbola eyes. If the hyperbola eyes open and move toward the center of the lemniscate figure the mineral is POSITIVE.

Push in the quartz wedge with its axis of least elasticity perpendicular to the line joining the hyperbola eyes. If these eyes open and move toward the center of the lemniscate figure, the mineral is NEGATIVE.

Of course, if in either case the eyes contract and move outwards, this is proof, when the axis of least elasticity of the quartz wedge is perpendicular to the line joining the hyperbola, that the mineral plate is POSITIVE ; but if they move outward when the axis of elasticity is parallel to the chosen line, the mineral is NEGATIVE.

This method is less satisfactory in practice than the one where the eyes open and move inwards.

(b) The above method given in our text books can be supplemented by one that can be employed in numerous cases when both of the hyperbola eyes cannot be seen, but only one of them or only the lemniscate arcs. In either of these cases the positive or negative character of the mineral plate can be ascertained; if one can determine the position of the line joining the hyperbola eyes or optic axes, by the form of the interference figures, by the position of the larger arm of the cross or by any other means. When this direction is observed, place the arcs so that the direction of the line joining the hyperbola vertices shall be perpendicular to, or bisect, them; also have this line make an angle of 45° with the cross hairs as

before. Push in the wedge with its axis of least elasticity perpendicular to the arcs or parallel to the line joining the hyperbola eyes. If the lemniscate arcs move in towards the center of the field with their convex side forwards the mineral is POSITIVE.

Push in the wedge with its axis of least elasticity tangent to the arcs or perpendicular to the line joining the vertices. If the arcs then move in with their convex side forwards the mineral is NEGATIVE. If the arcs move outwards with their concave side forwards the mineral in the first position of the wedge is NEGATIVE, and in the second position POSITIVE.

(c) If the distance between the hyperbola eyes is not so great but that they lie within the field of view, the mica and gypsum plates can both be employed to determine the positive and negative characters when the lemniscate figure is placed as before, with the line joining the hyperbola eyes forming an angle of 45° with the cross hairs of the eye piece. Insert either the mica plate with its axis of least elasticity parallel to the chosen line, or else insert the gypsum plate with its axis of least elasticity perpendicular to the chosen line. With either plate in this position the arcs on one side of the hyperbola eyes will enlarge and those on the other side contract. If the arcs that lie on the inside of the eyes, or nearest the center of the figure, enlarge, and those on the outside contract, the mineral is POSITIVE. On the other hand, if the arcs nearest the center contract and the outside arcs expand the mineral is NEGATIVE. This method can be used with plates that have too great an axial divergence to admit of their determination when the unsymmetrical cross is placed with its arms parallel to the cross hairs.

III. CHROMATIC SCALE.

Many students find it difficult to follow the color scales given in most text books of petrography owing to the numerous subdivisions of the scales. This difficulty can be obviated in part by each student making for himself a color scale suited to his eyes and experience. It is found that many students mistake their ignorance of the names of color tints for color blindness. The scale is made by placing the quartz wedge on the stage of the microscope with the nicols crossed. Then

push the wedge with its thin end forwards through the field of view of the microscope. Note the colors as they rise in the scale, as the successively thicker portions of the wedge pass in view. The scale thus noted will be suited to the wedge employed and to the student using it at that stage of his experience. The operation can be repeated with the nicols parallel if desired.

IV. SECTION AND PLATE.

I have found it convenient in practice to distinguish the terms "section" and "plate" in the microscopic study of minerals and rocks as follows:

The term "section" is employed to indicate the entire mass of the rock or mineral that is carried by the glass slide used on the stage of the microscope. The term "plate" is introduced to designate a particular section or slice of mineral or other substance that forms a part of the rock or general mass carried by the glass slide. A "section" is composed of "plates." A rock "section" is usually made up of many mineral "plates" either held together by intercrystallization or by some cementing material which material in its turn lies in an irregular "plate" or in "plates."

"Plate" is never the equivalent of "section," unless a single "plate" of one mineral forms the entire "section."

THE GEOLOGY OF THE KEWEENAWAN AREA IN NORTHEASTERN MINNESOTA. II.

By A. H. ELFTMAN, Minneapolis.

Part II. GEOLOGY OF THE KEWEENAWAN SERIES.

CHAPTER I. STRATIGRAPHY.

I. Historical Review.

The Keweenawan rocks of northeastern Minnesota are distributed over an area of about 4,500 square miles, and considerable has been written concerning this area. In view of the great diversity of opinions expressed, and as much that has been written consists of details regarding the geographical distribution of the different members of this series, and

also because this paper attempts in part to reconcile conflicting opinions, it has been thought best to present a brief statement of the results reached by each investigator. The term Keweenawan, as used by the writer, covers the rocks included by Irving in this series. At the end of this chapter is a list of papers relating to the geology of this area.

Norwood,[1] in 1852, gives many details as to the geology of the Minnesota coast of lake Superior. Some of the rocks were considered to be of igneous origin, but the greater part were referred to as metamorphosed sedimentaries.

Eames,[2] in 1866, mentions trap, greenstone, sandstone and metamorphic rocks.

Kloos,[3] in 1871, mentions the gabbro at Duluth and the porphyrytes along the Minnesota coast. The same author,[4] in 1871, describes gabbro, melaphyre, porphyries, amygdaloids and dike rocks in the vicinity of Duluth; and also,[5] in 1877, further describes the igneous rocks at Duluth, and shows that the melaphyre passes insensibly into the amygdaloids.

Streng and Kloos,[6] in 1877, give a petrographical description of several rocks from Duluth. The igneous rocks at the western end of lake Superior are referred to the Potsdam age.

Winchell (N. H.),[7] in 1879, refers the igneous rocks along the Minnesota coast of lake Superior to the Cupriferous series. These rocks are associated with extensive metamorphic shales, sandstones, quartzytes and conglomerates.

Winchell (N. H.),[8] in 1880, regards the Cupriferous series as Potsdam. The gabbro at Duluth is intimately associated with a metamorphic syenitic granite. All stages of metamorphism, from the crystalline granite to the unchanged sedimentary layers, were noted.

Hall (C. W.),[9] in 1880, finds the Cupriferous series, between the mouths of Temperance and Devil's Track rivers on lake Superior, to consist of basic igneous rocks and interbedded strata of sandstone and conglomerate. The Sawteeth mountains are due to combined igneous action, the folding of sedimentary strata and erosion.

S[illegible] in 1880, describes the [illegible] series in the [illegible] river valley. The [illegible] rocks are bedded.

varying from a foot to many feet in thickness. The Keweenawan rests unconformably upon the Saint Louis river slates and is older than the lake Superior red sandstone.

Winchell (N. H.),[11] in 1881, gives many details observed along the lake Superior coast from Duluth to Pigeon point. The same author,[12] in 1881, in a discussion of the rocks of northeastern Minnesota, considers the acid red rocks forming the Palisades, and occurring extensively in the vicinity of Grand Marais and in numerous other places, to be metamorphosed sandstone, red shales and conglomerates. "On passing inland from the lake shore back of Grand Marais, and up the Devil's Track and Brulé rivers, the red semi-metamorphic slates of the shore can be followed over a wide extent of territory, gradually becoming more changed and crystalline in receding from the lake shore." The same author,[13] in 1882, adds numerous details concerning the geographical distribution of the Cupriferous. The gabbro, which is found to have wide extent, and its associated red granites, are considered as a part of this series.

Irving,[14] in 1883, gives a systematic account of the copper-bearing rocks of lake Superior, and the petrographical characters of the different members of the series are given in detail. The Keweenawan beds in Minnesota are referred to the lower division of that series. The following six subordinate groups, having a total thickness of upwards of 20,000 feet, represent this series.

1. The Saint Louis River gabbro and associated red porphyries. This group comprises the basal gabbro, and consists of orthoclase-gabbro, orthoclase-free gabbro, fine grained diabase, augite syenite, granitic porphyry and felsitic porphyry. The thickness was estimated at about 6,000 feet.

2. The Duluth group. This group was recognized at both ends of the Minnesota coast, and has a maximum thickness of 5,000 feet. It consists largely of a succession of heavy but sharply defined beds of fine grained rocks belonging to the ashbed diabases and diabase porphyrytes. Coarse grained orthoclase-free gabbro, thin amygdaloids and a little interleaved detrital matter are also present.

3. The Lester River group. This group was recognized at both ends of the coast, and has a thickness of 2,600 feet.

It consists of distinct beds of diabase porphyryte, diabase, amygdaloid, coarse grained gabbro and granite porphyry.

4. The Agate Bay group. This group forms the coast line for 35 miles below the mouth of Lester river, and has a thickness of 1,500 feet. It consists of relatively thin beds of diabase, olivine diabase, diabase porphyryte, amygdaloids, sandstones and conglomerates.

5. The Beaver Bay group. This group is found at both ends of the coast, and has a maximum thickness of 6,000 feet. It consists of beds of black, coarse grained, olivine gabbro, ashbed diabases, diabase porphyrytes, amygdaloids, red felsitic porphyries and granite-like rocks.

6. The Temperance River group. This group forms the middle of the Minnesota coast, and has a thickness of 2,500 to 3,000 feet. In its composition and structure it is analogous to the Agate Bay group.

The igneous origin of all the rocks, excepting a few thin beds of sandstone and conglomerate, is emphasized. Numerous faults are mentioned, but none with a displacement of over 100 feet were recognized. The absence of volcanic ash was noticed. The eruptive rocks include basic, intermediate and acid kinds, but there is no such chronological relation between these as is often found in more recent eruptives. The series rests unconformably upon the Animikie or Upper Huronian slates in the Saint Louis river valley and in the vicinity of Grand Portage bay.

Winchell (N. H.),[15] in 1884, refers the igneous gabbros and dolerytes, together with their metamorphic products, to the Potsdam formation. The same author,[16] in 1885, finds the Animikie slates and quartzytes overlain by the gabbro and red granite of the Mesabi range, which is in turn overlain by the trap rocks of the Cupriferous.

Winchell (Alex.),[17] in 1887, gives detailed observations made on an extensive trip in northeastern Minnesota. The northern limit of the gabbro was determined in a number of localities, and some peculiar contact rocks were noted.

Winchell (N. H.),[18] in 1887, gives many details and publishes a preliminary geological map of a part of northeastern Minnesota embodying the results of the field investigation up to that time. The gabbro lies unconformably upon the Animikie, Keewatin and granitic rocks associated with these.

Wadsworth,[19] in 1887, gives petrographical descriptions of many of the Keweenawan rocks.

Irving,[20] in 1887, emphasizes the structural break between the Huronian and the Keweenawan formations. The Potsdam sandstone rests upon the eroded surface of the Keweenawan. The same author,[21] in 1888, published a geological map of northeastern Minnesota. The Keweenawan is divided into two large divisions, the basal gabbro and the remainder consisting of the upper five groups described in 1883.

Winchell (Alex.),[22] in 1888, gives further details of the gabbro area along its northern limit.

Winchell (N. H.),[23] in 1888, describes the rocks along the northern boundary of the gabbro from Gunflint lake westward. The trap (gabbro?) lies upon the Animikie in many places. The gabbro lies upon the Pewabic quartzyte and the Keewatin formations. The Pewabic quartzyte is placed above the Animikie. The same author,[24] in 1889, gives a summary of the results of work on the crystalline rocks in northeastern Minnesota. The gabbro, red rocks and Keweenawan rocks are referred to the Paradoxides horizon of the Potsdam age. In general the conclusions and facts presented agree with those expressed in earlier reports.

Winchell (H. V.),[25] in 1889, gives many details regarding the geographical distribution of the Keweenawan. The gabbro embraces large fragments of Animikie quartzyte and slate, thus showing its later origin. The gabbro is intersected by greenstone dikes, and in places gave the impression that it is on top of the Cupriferous, and hence more recent.

Grant,[26] in 1889, gives numerous details regarding the geographical extent of the Keweenawan. The gabbro is cut by veins or dikes of syenite, and the contact between these rocks is always distinct. Portions of the Animikie beds are included in the gabbro.

Winchell (N. H.),[27] in 1889, considers the basic eruptives consisting largely of gabbro and following the Animikie, and those of the Cupriferous formation as representing separate epochs of eruptive activity.

Winchell (N. H. and H. V.),[28] in 1890, describe the gabbro titaniferous magnetites of the Mesabi range.

Winchell (N. H.),[29] in 1891, gives numerous details. The great gabbros of the Cupriferous series and the Pewabic quartzyte are regarded as lying below the Animikie. Large boulders of gabbro and of red syenite occur abundantly in the later traps of the Cupriferous.

Winchell (N. H. and H. V.),[30] in 1891, describe the iron ores of Minnesota. The gabbro of the Mesabi hills, red granite, quartz porphyry and red felsite, are called the Norian formation. This lies below the Animikie, above which are the Keweenawan (Potsdam?) trap rocks, tuffs, red sandstones, and conglomerates.

Bayley,[31] in 1892, gives the results of a microscopic examination of rocks from the vicinity of Akeley lake. The rocks designated Pewabic quartzyte by the Minnesota geologists are granulitic phases of the gabbro and crystallized aggregates of quartz. None of them are sedimentary rocks.

Van Hise,[32] in 1892, reviews the literature up to that time upon the Archean and Algonkian of the lake Superior basin and accepts Irving's views of the Keweenawan.

Grant,[33] in 1893, finds the gabbro lying upon the granite and mica schists from Birch to Kekequabic lakes. Many detailed observations are given.

Winchell (H. V.),[34] in 1893, places the gabbro above the Animikie slates and the Giant's range granite.

Winchell (N. H.),[35] in 1893, divides the Keweenawan (Nipigon) into an upper and a lower division. The lower division is divided into the Norian (gabbros and anorthosytes) and the traps and amygdaloidal rocks of the northwest coast of lake Superior.

Grant,[36] in 1893, finds that probably some of the gabbro contact rocks are part of the gabbro, while others are metamorphosed sediments.

Winchell (N. H.),[37] in 1893, discusses the Norian of the Northwest.

Lawson,[38] in 1893, gives a petrographical description of the anorthosytes of the Minnesota coast of lake Superior. The anorthosytes are considered to represent, in part, the eroded surface of a pre-Keweenawan formation to which the name Carltonian is given. In the opinion of the author, the Keweenawan is not over 2,400 feet thick.

Lawson,[39] in 1893, shows that the trap sheets associated with the Animikie slates are intrusive sills whose age is considered to be post-Keweenawan (Keweenian). On the Canadian side of lake Superior these sills were found in the Keweenawan, and the author states his opinion, "that many of the heavy sheets of dark diabase or gabbro which prevail on the Minnesota coast, particularly in its eastern portion, and which have been described and referred to by former observers as volcanic flows of Keweenian age, are laccolitic sills."

Bayley,[40] in 1893, gives in detail the petrography, relations and field occurrences of the eruptive and sedimentary rocks of Pigeon point. Bayley,[41] reviews the basic, massive rocks of the lake Superior region. The great gabbro of northeastern Minnesota, whose petrographical characters are described with considerable detail, has a typical granitic structure and shows the characters of an intrusive rock. It differs essentially from all of the basic intrusive rocks of the Animikie and from all other Keweenawan basic rocks, none of which have a typical granitic structure. Along the northern border of the gabbro are peculiar basic and quartzose rocks which are regarded as peripheral phases of the gabbro. The author concludes that further field work will probably show that the gabbro is either a batholite, well toward the base of the Keweenawan series, or that it is an eroded mass upon top of which the later Keweenawan beds have been deposited.

Grant,[42] in 1894, states that the gabbro varies in mineralogical composition, at times being entirely composed of feldspar and again exceedingly rich in olivine. The gabbro contains fragments of the Animikie slates. The fine grained gabbros are older than the main mass of the gabbro. The acid eruptives in the vicinity of Brulé lake are later than the gabbro and probably represent the deep seated magmas that produced the extensive acid surface flows seen along the Minnesota coast.

Elftman,[43] in 1894, divides the Keweenawan into the gabbro, diabase, red rock and later dike groups. The anorthosytes of the Minnesota shore of lake Superior are shown to be detached blocks inclosed in later trap rocks, and they do not represent the eroded surface of an older formation.

Grant,[44] in 1894, describes the conglomerates on Grand Portage island, and places it at the base of the Keweenawan.

Elftman,[45] in 1895, describes the bedded and banded structure of the gabbro and an area of troctolyte.

Winchell (N. H.),[46] in 1895, states that the eruptive rocks in Michigan, Wisconsin and Minnesota which have been included in the Keweenawan consist of two widely different series, of widely separated ages. The older of these series, the Norian, includes the great gabbro mass, augite syenites, the quartz-porphyries of the Great palisades and elsewhere along the Minnesota coast, and the anorthosytes. The more recent or Keweenawan proper includes the basal conglomerate at Grand Portage island, at Baptism river and at Duluth, and the later trap flows, some of which pass below the Norian rocks at the Great palisades. The "black rocks" in the Brulé lake region are regarded as part of the Animikie slates.

Van Hise,[47] in 1893, 1895 and 1896, reviews and comments upon current pre-Cambrian literature.

Winchell (N. H.),[48] in 1897, discusses the nature and position of the conglomerate in the Puckwunge valley. This conglomerate is correlated with that at Grand Portage island, Baptism river and Duluth. The unconformity below this conglomerate separates the Norian from the Keweenawan.

Winchell and Grant,[49] in 1896, describe volcanic ash.

2. *Results of the Present Investigation.*

The preceding review of the literature upon the Keweenawan of northeastern Minnesota shows the existence of a great diversity of opinions as to the proper subdivision of this series. All admit that several subdivisions are possible. Thus far no two geologists who have written concerning this area have agreed upon this point. The observations were confined largely to a narrow strip along the lake Superior coast and the northern half of the gabbro mass. Between these limits the region remained practically a "terra incognita."

The writer, in 1893, began to map this formation for the Geological and Natural History Survey of Minnesota, and has devoted the greater part of five seasons of field study to this work. It soon became apparent that none of the suggested subdivisions could be followed to any extent. Nearly all of

them had some points which could be recognized over the entire area. The "terra incognita" usually did not show the phenomena which had been predicted for it. The following brief outline is given in order that the reader may better understand the detailed descriptions as they are given in the succeeding chapters. The results given below are based entirely upon the writer's investigation and the petrographical descriptions of the groups are taken from the series of rocks collected by the writer for the Minnesota Survey.

An important obstacle in the way of getting a satisfactory subdivision of the Keweenawan has been the failure to recognize the extent of the faulting. It is evident that there is a belt near the lake Superior coast which contains a series of faults, some of which show a displacement of over 1,000 feet. This belt is conspicuous for its peculiar topography and is known as the Sawteeth mountains.

The proposed subdivision of the Keweenawan series is based upon the chronologic succession, the stratigraphic continuity and the distinctive lithologic characters of each member. The eruptive rocks of each member possess a strong similarity in lithologic characters and are closely allied in their genetic relationship. This suddivision eliminates the supposed promiscuous chronologic relations of the acid, basic and intermediate eruptive rocks. The members, here proposed, are, in order of their age, the Gabbro, the Beaver Bay Diabase, the Red Rock, the Temperance River and the Later Diabase.

The Gabbro member. This includes essentially the basal gabbro of Irving and the gabbro of the Mesabi hills of Winchell. It is entirely of an intrusive nature and appears to be one mass, the proportion of whose mineral constituents vary so that locally well defined varieties of the rock are recognized. On its northern side the gabbro is in contact with pre-Keweenawan formations, and on its southern border it is associated with later members of the Keweenawan series.

The Beaver Bay Diabase member. This member has not been found in contact with the preceding member. The area between the two is occupied by parts of the later members. In the vicinity of Brulé lake are some rocks which may possibly be older than the gabbro, but these are not associated

with the Beaver Bay diabase. The member consists chiefly of the massive flows of coarse diabase which inclose the anorthosytes of the Minnesota coast. Above these are numerous thinner flows of diabase, diabase porphyryte and amygdaloidal diabase. In the upper part of the member are thin layers or patches of volcanic ash. It is evident that this member consists of basic surface flows with more or less volcanic fragmental rocks. The rocks as exposed above lake Superior show that during the accumulation of this member the surface was not submerged beneath the ocean. The fragmental rocks point toward a formation upon an exposed surface. The position of this member in the series is such that it may be regarded as contemporary with the gabbro. Both consist of basic rocks; the one is intrusive and the other effusive. These and other facts indicate that the Gabbro and Beaver Bay Diabase members are complementary parts of one eruptive epoch. In the present paper the two are considered as two members in order to establish the individual characters of each. When this is done a further correlation may be attempted. The rocks included in this member include part of the Duluth, Lester River, Agate Bay and Beaver Bay groups of Irving. The name Beaver Bay Diabase is given to the member because all of the essential characters appear in the region of which Beaver Bay forms the central point. This diabase also forms the greater part of Irving's Beaver Bay group, and is usually referred to, by him, as "black olivine gabbro."

The Red Rock member. This consists of intrusives and their equivalent effusives. The former include granite and augite syenite which occur extensively in the region between the preceding two members and as bosses and dikes within the gabbro. Numerous dikes also cut the Beaver Bay diabase, and extensive surface flows of quartz porphyry lie upon it. All of the rocks are highly acid. The Red Rock member, so named on account of the persistent red color of the rocks, succeeds the Gabbro and Beaver Bay Diabase members and presents similar physical characters concerning its origin. The member includes the red rocks associated with the Saint Louis River gabbro, and parts of the Lester River and Beaver Bay groups of Irving.

The Temperance River member. Between this and the preceding members is a considerable unconformity. The older members were extensively eroded. In places a conglomerate and quartzyte over one hundred feet in thickness form the basal strata. Upon the quartzyte and contemporaneous with part of it are found basic and intermediate surface flows. The flows which followed consist of diabase and diabase porphyryte, with a strong development of amygdaloidal structure in the upper part of each flow. Numerous interbedded layers of sandstone, sometimes 250 feet thick, though usually from a few inches to a few feet, are found in all parts of the member. In certain parts of the older members are found several areas of basic intrusive rocks varying in structure from that of a gabbro to that of a diabase. These are tentatively correlated with this member, and may probably represent fissures or vents through which the surface flows were ejected. The land was submerged, and it is noticeable that the volcanic activity decreased and the deposition of sedimentary rocks increased toward the top of the formation. This member includes the greater part of the Agate Bay, the eastern end of the Duluth and all of the Temperance River groups of Irving. The unconformity at the base of the Temperance River member, in places, has been identified by Prof. N. H. Winchell as the division line between the Norian and the Keweenawan. From the descriptions of these divisions, as given by Prof. Winchell, it is evident that part of his Norian belongs above and part of his Keweenawan belongs below this unconformity.

The Later Diabase member. A large number of diabase dikes and sills are found cutting all of the preceding members. The areal distribution of these is comparatively small. Since they are later than all of the rest of the Keweenawan at present found in this region, they are thrown into a separate member. These dikes may not all be of the same age. In this member are included rocks which are found in all of Irving's groups, especially the Duluth group south of Brulé lake. The "black rock" of Winchell forms a prominent feature of the group. This group occurs at numerous places along lake Superior coast and frequently is indistinguishable from the black diabases which it cuts.

3. Bibliography of the Keweenawan Area in Northeastern Minnesota.

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2. Report of the State Geologist on the metalliferous region bordering on lake Superior, Henry H. Eames. St. Paul, 1866, pp. 21. See also, Geological reconnaissance of the northern, middle and other counties of Minnesota, Henry H. Eames. St. Paul, 1866, pp. 58.

3. Geological rambles in Minnesota, J. H. Kloos. The Minnesota Teacher and Journal of Education, St. Paul, 1871, vol. iv, no. 6.

4. Geologische Notizen aus Minnesota, J. H. Kloos, Zeitschrift der Deutschen Geologischen Gesellschaft, 1871, Bd. 23, pp. 417-448, 648-652, map. Translated by N. H. Winchell, 10th Ann. Rept. Geol. and Nat. Hist. Survey of Minn., 1882, pp. 175-200.

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7. Sketch of the work of the season of 1878, N. H. Winchell. 7th Ann. Rept. Geol. and Nat. Hist. Survey of Minn., 1879, pp. 9-25.

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11. Preliminary list of rocks, N. H. Winchell. 9th Ann. Rept. Geol. and Nat. Hist. Survey of Minn., 1881, pp. 10-71.

12. The Cupriferous series in Minnesota, N. H. Winchell. Proc. Am. Assoc. Adv. Sci., 29th meeting, 1881, pp. 422-425. Same article in 9th Ann. Rept. Geol. and Nat. Hist. Survey of Minn., 1881, pp. 385-387.

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14. The Copper-bearing rocks of lake Superior, R. D. Irving. U. S. Geol. Survey, 1883, Monograph V, pp. 464, maps and plates. Chapter VII gives details concerning the Keweenawan in Minnesota.

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18. Geological report of N. H. Winchell. Ibid., pp. 209-399.

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21. On the classification of the early Cambrian and pre-Cambrian formations, R. D. Irving. 7th Ann. Rept. U. S. Geol. Survey, 1888, pp. 418-423, and plate XLI.

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23. Report of N. H. Winchell. Ibid., pp. 13-129.

24. Report of N. H. Winchell. 17th Ann. Rept. Geol. and Nat. Hist. Survey of Minn., 1889, pp. 5-74.

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30. The iron ores of Minnesota, N. H. and H. V. Winchell. Bull. 6, Geol. and Nat. Hist. Survey of Minn., 1891, pp. 430; with a geological map of northeastern Minnesota.

31. Notes on the petrography and geology of the Akeley lake region, in northeastern Minnesota, W. S. Bayley. 19th Ann. Rept. Geol. and Nat. Hist. Survey of Minn., 1892, pp. 193-210.

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33. Field observations on certain granitic areas in northeastern Minnesota, U. S. Grant. 20th Ann. Rept. Geol. and Nat. Hist. Survey of Minn., 1893, pp. 35-95.

34. The Mesabi iron range, H. V. Winchell. Ibid., pp. 126, 127.

35. Nomenclature of the pre-Silurian rocks of Minnesota, N. H. Winchell. 21st Ann. Rept. Geol. and Nat. Hist. Survey of Minn., 1893, table on p. 5. See also pp. 143-152.

36. The geology of Kekequabic lake. U. S. Grant, Ibid., pp. 29, 30. See also pp. 143-152.

37. The Norian of the northwest, N. H. Winchell. Bull. 8, Geol. and Nat. Hist. Survey of Minn., 1893, pp. i-xxxiv.

38. The anorthosytes of the Minnesota coast of lake Superior, A. C. Lawson. Ibid., pp. 1-23.

39. Laccolitic sills of the northwest coast of lake Superior, A. C. Lawson. Ibid., pp. 24-48.

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43. Preliminary report of field work in 1893, A. H. Elftman. Ibid., pp. 169-180.

44. Note on the Keweenawan rocks of Grand Portage island, north coast of lake Superior, U. S. Grant. Amer. Geol., vol. XII, pp. 437-438, 1894.

45. Notes upon the bedded and banded structures of the gabbro and upon an area of troctolyte, A. H. Elftman. 23rd Ann. Rept. Geol. and Nat. Hist. Survey of Minn., 1895, pp. 224-230.

46. A rational view of the Keweenawan, N. H. Winchell. Amer. Geol., vol. XVI, 1895, pp. 150-155. See also the series of articles "Crucial Points in the geology of the lake Superior region," Amer. Geol., 1895, vols. XV and XVI.

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48. Some new features in the geology of northeastern Minnesota, N. H. Winchell. Amer. Geol., vol. XX, 1897, pp. 50, 51.

49. Volcanic ash from the north shore of lake Superior, N. H. Winchell and U. S. Grant. Amer. Geol., vol. XVIII, pp. 211-213, 1896.

REVIEW OF RECENT GEOLOGICAL LITERATURE.

Palæontologiska notiser. Af GERHARD HOLM. (Geol. Fören. i. Stockholm Förhandl., Bd. 19, Hft. 6, tabl. 8-9, s. 457-482, Nov. 1897.)

4. *Om Bohemilla (?) denticulata Linrs. och Remopleurides microphthalmus Linrs.* Tafl. 8.

5. *Om skalspetsen hos Lituites.* Tafl. 9.

6. *Om förekomsten af en Pterygotus i Dalarnes Öfersilur.*

In the first of these three notes, Dr. Holm revises the description of

a new species of trilobite from Jemtland, described and figured by Linnarsson (Geol. fören. förh., Bd. 2, s. 495, 1875?), and by him referred with doubt to Barrande's genus *Bohemilla.* The author describes the revision of Barrande's work on the genus *Bohemilla* and family *Bohemillidæ* made by Dr. C. E. Beecher, based upon specimens in the Museum of Comparative Zoology, at Cambridge, Mass., wherein he affirms that there is no satisfactory basis for the genus *Bohemilla* and familly *Bohemillidæ*. Of this determination of Beecher, Dr. Holm appears to approve.

The specimens which authenticate the species *Bohemilla* (?) *denticulata* of Linnarsson, consist of a head and a pygidium preserved in the Swedish geological musem, at Stockholm. Dr. Holm, declares that this species agrees better with the genus *Angelina*, of Salter, than with any other, and so refers it. He also refers to *A.* (or *B.*) *denticulata* the pygidium connected by C. Wiman with *Telephus bicuspis* Ang.

Another species from the same horizon and district, *Remopleurides microphthalmus* Linrs. should according to Dr. Holm be referred to *Dicellocephalus.* He figures also a head for Angelin's *Centropleura serrata*, and claims that this also should be included in *Dicellocephalus*, as has been done by other authors. There is quite a close resemblance between this species and *D. finalis* Walcott of the Eureka district, Nevada, as Dr. Holm points out.

But the advantage of referring these Ordovician species to *Dicellocephalus*, without limitation is questionable; they have not the cylindrical glabella with transverse furrows of the typical species of *Dicellocephalus* of Owen and Hall. None of these species as shown by Hall ("Preliminary notice of the fauna of the Potsdam sandstone," of the upper Mississippi valley) have more than two spines on the pygidium. See also Trans. Roy. Soc. Can., Vol. X, p. 11.

While Dr. Holm has transferred one of Linnarsson's species of this fauna of Jemtland to the above genus, he has removed another from it. *D. billingsi* is transferred to the subgenus *Parabolinella* of Brögger. A complete example also enables Dr. Holm to assert that the *Triarthrus jemtlandicus* of Linnarsson is the same as *Triarthrus becki* Green.

5. "*On the apex of the shell in Lituites.*" Sections of the shell of *Lituites perfectus* Wahl., of which figures are given, show the peculiar courses of the siphon. It begins on the outer margin of the first chamber, and about the fourth or fifth chamber becomes central; subsequently it works still further towards the inner side of the shell, and for the first whorl is about a third from this side; subsequently it becomes more central.

6. "*On the Occurrence of a Pterygotus in the Upper Silurian of Dalecarlia.*" Dr. Holm says fragments of a species of this genus were collected by G. von Schmalensee from a dark grey limestone in the above district in 1895, He refers the specimens to the species *P. osiliensis* Fr. Schmidt.

Dr. Holm's article is accompanied by two excellent plates showing *D. microphthalmus*, *D. serratus* and *Lituites perfectus.* G F. M.

A Revision of the Puerco Fauna. By W. D. MATTHEW. Bulletin Amer. Mus. Natural History, vol. IX, Art. XXII, p. 259; New York, Nov. 16th, 1897.

This article is the outcome of a careful study of the original material on which the late Prof. E. D. Cope based his description of the Puerco fauna. To this material has been added the collection of the Museum expeditions of 1892 and 1896 under the guidance of Dr. J. L. Wortman, so that the author has had exceptional opportunities to obtain a thorough knowledge of this primitive fauna of the placental mammals.

Being the starting point in America so far as is known of so many recent orders of mammals this fauna, nothwithstanding the fragmentary condition of most of the material, is of the greatest interest. In dealing with it, Prof. Cope had to depend chiefly on jaws and teeth, and, even with the new material gathered by the Museum expeditions, only for a few forms can the skeletal characters be described.

Dr. Wortman has described the stratigraphy of the beds and written a paper on the Edentata.. The work of Dr. W. D. Matthew has consisted in a rearrangement of the species and reduction of their number. This removal of unsound species and readjustment of the remainder is a most useful work, as giving a better basis for generalizations as to the bearing of this fauna on later Eocene and other Tertiary mammals.

One important result of late studies and of this review is the discovery that the Puerco group really contains two faunas, contained in three fossiliferous layers, to the two lower of which the name Puerco is now confined, the upper being designated the Torrejon fauna. The combined faunas contain the following element:

"1. The Mesozoic group of Multituberculates culminates in the Puerco and dies out in the Torrejon, true rodents coming in to take its place.

"2. The main body of the fauna is composed of the primitive types from which sprang the ungulates on the one hand, and the later creodonts and carnivores on the other. In the Puerco these two divisions are hardly distinguishable; in the Torrejon they are clearly separable, although still closely allied, and the subdivisions of each group are foreshadowed. But it must not be supposed that we have here the direct ancestors of all the later types; on the contrary, there are comparatively few forms, even in the Wasatch, that are descended from known basal Eocene species, and these are not the persistent types. It is clear that a large addition to the fauna must be made before we will come across the direct ancestors of most of the modern Ungulata. The basal Eocene carnivores and ungulates were evolving into types corresponding to the modern differentiation, but to a great extent analogous only, and not ancestral.

"For such primitive carnivores the term *Creodonta* is universally used. For the corresponding group of primitive ungulates the term *Condylarthra* will here be used, making it nearly equivalent to the hypothetical *Protungulata*.

"3. A few more specialized lines may be separated from this main group. The *Edentata* are already well advanced in their differentiation. The *Amblypoda* and *Rodentia* are just beginning, but clearly recognizable. A fourth type is allied to the *Primates*."

Two tables are given—one to exhibit the relation of the Puerco and Torrejon faunas to the later Tertiary faunas. This shows "the difference between the Puerco and Torrejon faunas to be mainly in the poverty of the former in families. This is not due to any scarcity of specimens or species; it points to a large immigration at the beginning of the Torrejon. Another considerable immigration must have taken place before the beginning of the Wasatch."

The second table shows the families and species of the animals of the Puerco and Torrejon and the number of examples of each species examined, in some cases over one hundred. Thirty-one species are reckoned to the Puerco and forty-four to the Torrejon. Most of these species were originally described by Cope, four are ascribed to Osborn and Earle, and one to Wortman; two new species are described by Dr. Matthew, and another distinguished but not described.

There are several suggestive discussions of genera and families, especially the ? *Rodentia* (p. 265) *Triisodontidæ* (p. 277) *Clenodon* (p. 291) *Condylarthra* (p. 293 and 321) *Anisonchinæ* (p. 297) *Phenacodontidæ* (p. 299) *Euprotogonia* (p. 305) *Mioclænidæ* (p. 311), also a note on the foot structure of the basal Eocene mammal, on p. 320.

This article, with its full description of the archaic placentals of the Puerco and Torrejon faunas, accompanied, as it is, by cuts showing the dentition of most of them, and a full synonymy of the species, is a valuable addition to the history of the development of the Mammalia, and a convenient compendium for the student of these vertebrates.

G. F. M.

Geology of Massanutten Mountain in Virginia. By ARTHUR COE SPENCER. (Pamphlet, pp. 54, 3 plates and map Washington, 1897.)

Among the dissertations that have recently been issued there are none of greater interest than that on the geology of Massanutten mountain by Arthur Coe Spencer, of the Johns Hopkins University. It deals with a problem that is ordinarily much too large for the thesis required as the final outcome of graduate work in the university. But the treatment is as full and admirable as the subject matter is interesting and instructive. The area treated of is eight miles wide by forty-five miles long, lying between two parallel branches of the Shenandoah river.

After a general description of the main topographic features of the surrounding region, the stratigraphy, lithological characters, structure and local relief are considered. The principal effort is placed on the geological history of the region as elucidated by Massanutten. The conclusions are briefly summarized as follows: (1) After the deposition of the Cambro-Silurian limestone a land area was elevated opposite the region studied, with its seaward boundary in the vicinity of the present Blue ridge; (2) subsequent to this early revolution there were many

oscillations of the shore line resultant upon alternating elevation and subsidence, but the average position of the coast was not greatly changed from the position first assumed, for it was now on one side and now on the other of the Martinsburg shore; (3) the Massanutten syncline marks the site of an off-shore zone of maximum deposition, and is therefore illustrative of the hypothesis of original synclines: (4) the general post-Carboniferous folding of the Appalachian province was shared by the Massanutten region; (5) since Paleozoic time the region has been several times elevated, suffering, during the intervals between the uplifts, more or less complete degradation, at least three and perhaps four such uplifts being recognized in remnants of base level surfaces; (6) the latest upward movement of the land has been so recent that its effect is still evident in the grades of the rivers of the region.

Not the least valuable features of the paper are the synoptic arrangement throughout, terseness of statement, and the general absence of all those unnecessary details which so often burden most literature of this kind.

C. R. K.

MONTHLY AUTHORS' CATALOGUE
OF AMERICAN GEOLOGICAL LITERATURE, ARRANGED ALPHABETICALLY.*

Agassiz, Alexander.

The islands and coral reefs of the Fiji group. (Am. Jour. Sci., ser. 4, vol. 5, pp. 113-123, Feb. 1898.)

Blake, W. P.

Native sodium carbonate. (Eng. and Min. Jour., vol. 65, p. 188, Feb. 12, 1898.)

Campbell, M. R.

Earthquake shocks in Giles Co., Va. (Science, new ser., vol. 7, pp. 233-235, Feb. 18, 1898.)

Cohen, E.

Über ein neues Meteoreisen von Locust Grove, Henry Co., Nord-Carolina, Vereinigte Staaten. (Sitzungsb. d. k. preus. Akad. d. Wissensch. zu Berlin, phys.-math. Cl., 1897, VI, pp. 76-81.)

Cohen, E.

Das Meteoreisen von Forsyth Co., Georgia, Vereinigte Staaten. (Sitzungsb. d. k. preus. Akad. d. Wissensch. zu Berlin, phys.-math. Cl., 1897, XVI, pp. 386-396.)

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*This list includes titles of articles received up to the 20th of the preceding month, including general geology, physiography, paleontology, petrology and mineralogy.

Elftman, A. H.

The geology of the Keweenawan area in northeastern Minnesota. (Am. Geol., vol. 21, pp. 90-109, pl. 11, Feb. 1898.)

Ells, R. W.

Formations, faults and folds of the Ottawa district. (Ottawa Naturalist, vol. 9, pp. 177-189, Jan. 1898.)

Ells, R. W.

Recent conclusions in Quebec geology. (Ottawa Naturalist, vol. 11, pp. 173-176, Dec. 1897.)

Gilbert, G. K.

A proposed addition to physiographic nomenclature. (Science, new ser., vol. 7, pp. 94-95, Jan. 21, 1898.)

Gilpin, E., Jr.

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Clay-veins vertically intersecting Coal Measures. (Geol. Soc. Amer., Bull., vol. 9, pp. 35-58, Jan. 18, 1898.)

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Cote Sans Dessein and Grand Tower. (Am. Geol., vol. 21, pp. 86-90, pl. 10, Feb. 1898.)

Orton, Edward.

Geological probabilities as to petroleum. President's address. (Geol. Soc. Amer., Bull., vol. 9, pp. 85-100, Jan. 24, 1898.)

Pratt, J. H.

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On continental elevation of the Glacial epoch. (British Ass. Adv. Sci., Sec. C, Toronto, 1897; 2 pp.)

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Great changes of level in Mexico and the interoceanic connections. (Geol. Soc. Amer., Bull., vol. 9, pp. 13-34, pls. 1-5, Dec. 31, 1897.)

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An account of the researches relating to the Great lakes. (Am. Geol., vol. 21, pp. 110-123, Feb. 1898.)

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Niagara gorge and Saint Davids channel. (Geol. Soc. Amer., Bull., vol. 9, pp. 101-110, Jan. 25, 1898.)

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Shell-bearing drift on Moel Tryfan. (Am. Geol., vol. 21, pp. 81-86, Feb. 1898.)

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Zirkelyte: A question of priority. (Am. Geol., vol. 21, pp. 133-134, Feb. 1898.)

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Some methods of determining the positive or negative character of mineral plates in converging polarized light with the petrographical microscope. (Jour. Applied Microscopy, vol. 1, pp. 20-21, Feb. 1898.)

[Walcott, C. D.]

Sketch of Charles D. Walcott. (Appletons' Pop. Sci. Monthly, vol. 52, pp. 547-553, portrait, Feb. 1898.)

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Four new Australian meteorites. (Am. Jour. Sci., ser. 4, vol 5, pp. 135-140, Feb. 1898.)

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Stratigraphy and structure of the Puget group, Washington [Abstract. (Geol. Soc. Amer., Bull., vol. 9, pp. 2-6, Dec. 30, 1897.)

CORRESPONDENCE.

CORRELATION OF MORAINES WITH BEACHES ON THE BORDER OF LAKE ERIE. In two papers published in the American Journal of Science (April, 1892, and July, 1895,) I have advanced the view that certain moraines on the south and east borders of lake Erie are correlatives of beaches which encircle the western end of the Lake Erie basin, an interpretation which signifies that while a lake was occupying the district inclosed by these beaches, the ice-sheet was occupying districts to the east. This interpretation was based upon studies carried on in part by Mr. Gilbert and in part by myself, Mr. Gilbert's studies being confined mainly to the beaches and mine to the moraines. Later studies by Mr. Warren Upham, at Cleveland, and by Prof. H. L. Fairchild, in western New York, the results of which are published in the Bulletin of the Geological Society of America (Upham, Vol. VII, March, 1896, pp. 340-345, and Fairchild, Vol. VIII, March, 1897, pp. 269-281), have brought to light the continuation of these beaches to points farther east than had previously been observed. It seems necessary, in view of these observations, that a brief supplementary statement should be made. I am especially prompted to do this because Dr. Spencer has intimated in the February American Geologist that these later studies have removed the supposed evidence of ice occupancy of the eastern part of the region during the formation of beaches in the western part, and that they sustain his cherished view that the shore lines are marine. In this "diagnosis" Dr. Spencer departs from the views of Mr. Upham and Prof. Fairchild, as well as from those of Mr. Gilbert and myself.

The view that the beaches in the western end of the Lake Erie basin pertain to a glacial lake has been adopted after due consideration of other hypotheses. The nature of the outlet has been carefully looked into. The pioneer work by Mr. Gilbert, in the Maumee valley of northwestern Ohio and adjacent parts of Indiana brought to light the southwestern outlet to the Wabash, an outlet which was clearly recognized by him to be the product of a stream. Mr. Gilbert likened the upper twenty-five miles of the outlet to the Detroit river, while the portion immediately below is compared to the Niagara at Buffalo, where it

rushes over the outcrop of the Corniferous limestone, the descent being comparatively rapid (Geology of Ohio, Vol. I, 1873, p. 550). So far as I am aware, no subsequent observers have questioned the view that this outlet is the product of a stream of water having rapid descent. The outlet has been examined in some detail by Dr. C. R. Dryer, of the Indiana Geological Survey, by Mr. F. B. Taylor, the well known glacial geologist, and also by the present writer. The current was sufficiently swift to sweep away the greater part of the detritus brought in by tributary streams, as well as to excavate a channel in the glacial deposits having an average width of about one mile and depth of 50 feet or more. In this connection it may be remarked that outlets from basins farther west have given equally clear evidence that the lakes which discharged through them stood much above sea level. The Chicago outlet, for example, presents rapids near Joliet, where a descent of seventy feet was made in only nine miles.

At the time of the discovery of the Wabash outlet, Mr. Gilbert advanced the view that the lake was held in at the east by a land barrier, and concluded "that the Wabash outlet is now, in its relation to the other parts of the great rim, not less than 170 feet higher than it then was." (See p. 551 of work cited.) The view subsequently advocated by Mr. Gilbert, that the lake was held in by an ice barrier at the east, was adopted only after it was found impossible to account for the presence of the lake by a land barrier. With this recognition of the high elevation of the lake and the absence of a land barrier, has come the general assent to glacial dams as the only barrier available. And yet in the article referred to, Dr. Spencer states (p. 118) that he has postponed further study partly on account of the prejudice against post-glacial subsidence, thus implying that the views held by the advocates of glacial dams are due to prejudice rather than a result of logical reasoning.

Having now stated the conditions concerning the Wabash outlet and the absence of evidence of a land barrier to account for the lake, we may turn to the localities examined by Mr. Upham and Prof. Fairchild and note the bearing which the further studies have upon the question of the correlation of the moraines with beaches.

Mr. Upham has traced the Leipsic beach from Big creek valley in the west part of Cleveland, where it had been supposed to terminate, eastward about seven miles to the east part of the city, and thence northward two or three miles. He considers it likely that the shore may be traced still farther and places a probable limit at Euclid, ten miles east of the center of the city, where one of the moraines which I have described fades out. Concerning the correlation of this beach with stages of the glacial recession, Mr. Upham makes the following remarks:

"Mr. Leverett has proved the successive lake stages to have been contemporaneous with stages of the glacial retreat defined by four distinct moraines. The Leipsic beach he supposed to have been wholly formed before, and during, the accumulation of the Newburg moraine.

. . . . From Big creek westward the Leipsic shore displays perhaps three or four times more wave cutting and resultant beach gravel and sand than in the vicinity of Brooklyn and east of the Cuyahoga valley. There, however, it is unmistakably continued northeastward beyond the more northern deposits of the Newburg moraine, so that the later part of the Leipsic shore work was done after the ice-sheet had receded from its Newburg boundary." (Bulletin, Geol, Society of America, Vol. VII, pp. 344, 345.)

It remains to be determined whether the beach extends eastward beyond the western terminus of the Euclid moraine. In case it is found to be developed farther east along the face of the Euclid moraine, it would follow that the lake was still maintained at this level after the ice had withdrawn from the moraine, and the extent of the beach along that shore will measure the distance to which the ice had withdrawn before the lake level had become lowered. The question of the lowering of the lake level, it should be noted, depends not upon the withdrawal of the ice from the moraine, but upon the opening of a lower outlet. This may have occurred either during the occupancy of the moraine or subsequent to it; in either case it would not affect the question of the existence of an ice barrier. The significant feature brought out by Mr. Upham is the marked change in strength of the beach upon passing eastward within the limits of the supposed correlative moraine. The portion west from (outside) the moraine is so strong that it has long been recognized, while the portion east has been found only after a series of close observations by a trained observer of beach phenomena; and this observer renders the verdict that the recently discovered eastward extension of the beach displays only one-third or one-fourth as much strength as the well known portion of the beach. The discriminating study carried on by Mr. Upham has served to bring out the relationship of the ice to the glacial lake more fully than my own studies, but has not invalidated the conclusions concerning the presence of an ice barrier at Cleveland.

The Belmore beach, as indicated in my second paper, probably extends eastward nearly to the eastern end of lake Erie. It is well defined as far as Sheridan, New York, and may possibly continue to Hamburg, though the beach is apparently less definite than west from Sheridan. From Hamburg eastward, so far as has yet been discovered, this beach has no continuation. Its probable correlation with moraines near the east end of lake Erie is set forth in the paper referred to, and so far as I am aware no evidence against this correlation has since been discovered. Much light concerning the outlet of the glacial lake at the stage when the Belmore beach was forming, has been shed by Mr. Taylor's studies in southwestern Michigan (Bulletin, Geol. Soc. America, Vol. VIII, Jan., 1897, pp. 39-46). From these studies it appears that at the time the Belmore beach was in process of formation the ice-sheet still occupied lake Huron and Saginaw bay. The outlet of the lake is found to have crossed the "thumb" of Michigan near its north-

ern point, and, after expanding into a small lake at the head of the Saginaw Bay basin, to have entered Grand river along what has been termed by Spencer the Pewamo outlet. Mr. Taylor's studies, as well as mine, sustain the interpretation that the eastern and northern boundaries of the lake were found in an ice barrier, and they apparently bring out more clearly than mine the relationship of the ice to the lake.

It remains to speak of the results of Prof. Fairchild's studies of the extent of lake Warren in western New York. The beach marking the upper limit of that lake (called by the writer the Crittenden, but probably the equivalent of Spencer's "Forest beach") has been traced eastward, from the supposed termination near Indian Falls, beyond the Genesee river. The eastern terminus is at present unknown. As at Cleveland, the beach is less well defined east from the supposed correlative moraines than west from them, yet there appears to have been more wave action in the portion discovered by Prof. Fairchild, than in the case of the Leipsic beach in the east part of Cleveland. The wave action is sufficiently marked to have attracted my attention, though no beach was noted in connection with it. This is set forth in the following statement taken from my paper in the American Journal of Science (pp. 18-19):

"Upon examining the district eastward from northwestern Genesee county (where the Lockport moraine and the Crittenden beach intersect), we found a narrow belt at about the level of the Crittenden beach where the drift forms seem to have been somewhat modified by the action of waves or currents of water. This is considered a possible lake level, or perhaps a lake outlet. There is a large amount of gravelly drift in this belt, but so far as discovered it is not arranged in beach lines, the surface being either plane or having a gentle undulation, as if the drift knolls had suffered reduction or modification by waves or currents. This gravelly drift occupies usually a breadth of two or three miles. In places it occupies the entire interval between the Lockport moraine and the drumlin belt which lies north of it."

Concerning the views expressed in my paper, Prof. Fairchild makes the following remarks (page 271):

"Some of the views guardedly expressed in that article are definitely confirmed, while others require modification. The Lockport moraine was, undoubtedly, the eastern limit of the Warren water for a considerable time, and correlates with the formation of the beach south of Crittenden. But the withdrawal of the ice-front from that portion did not produce immediate lowering of the water or terminate the beach-making process at the Crittenden level. The zone of sand and gravel drift described by Mr. Leverett as lying north of the Lockport moraine is the shore deposit of the enlarged lake, and is definitely bordered by the eastern extension of the beach.

"A comparison, as regards the time involved, of the beach east of Indian Falls, with the beach westward, is very difficult to make on account of the difference in the topographic relief. The Crittenden

beach is much more mature, but it lies nearly parallel with the contours of a comparatively smooth sloping plain, and the conditions favored the rapid maturing of the shore line. Eastward from Indian Falls the land surface is very uneven and the shore line lies transverse to the drumlin molding, which conditions would require a much longer time to straighten and mature the beach. With all allowances, the impression made upon the mind is that of somewhat less duration of the beach-making forces in the Genesee region."

With any criticism of my work which brings out more refined determinations than I have made I am in full sympathy. The studies by Prof. Fairchild, Mr. Upham, and Mr. Taylor, just noted, have all been helpful to a better understanding of the situation. No doubt as the work continues much more refined and delicate discriminations will become possible. Faith in the harmony of the universe inspires confidence that the features of debatable origin, in which Dr. Spencer has taken refuge as a defense against glacial dams (page 117) and which have as yet received less attention than they merit, will some time be found consistent with the already well established facts and principles of geology, among which facts it seems safe to include glacial dams.

Opportunity is here taken to state that, in presenting the name Crittenden for the principal beach of lake Warren, I had no intention of departing from the usage of naturalists, as intimated by Dr. Spencer (page 119). For I doubted its being the precise equivalent of the Forest beach. These doubts have in a measure been removed upon discussing the matter with Dr. Spencer. Although continuous tracing has not as yet been made, there seems little question that the Crittenden beach is the equivalent of the Forest. Such being the case the name Forest has priority. It may also be remarked that the name Belmore, suggested by Prof. N. H. Winchell, has priority over the name Ridgeway, suggested by Dr. Spencer.

Denmark, Iowa, Feb. 9, 1898. FRANK LEVERETT.

A NEW WELL AT ROCK ISLAND, ILLS.—A new well has lately been drilled by the Rock Island Brewing company on its premises near the crossing of Seventh avenue and Elm street in Rock Island, Ills. The curb of this well has an elevation of about 654 feet above sea level, and the water rose to within 44 feet of this hight. The first 100 feet of the hole was made twelve inches in diameter; the next 185 feet, eight inches; the next 240 feet, six inches; and the last 764 feet, five inches; the total depth of the well being 1,289 feet. There was a water-bearing stratum in the Trenton limestone, but the water from this rock was sulphurous and was shut off by a casing extending down to 912 feet below the top of the well. The drillers furnished me with a statement of the nature of the rocks which were penetrated. This is here given, with my own determinations in parentheses:

1. "Clay, 100 feet." (Loess and till, and possibly some coal-measure shale.) From 654 A. T. to 554 A. T.
2. "Limestone, 30 feet." (Devonian.) From 554 to 524.

3. "Limestone, with shale alternating, 395 feet." (The upper twenty feet, or so, possibly Devonian limestone, the rest is Niagara limestone with arenaceous shale in caverns.) From 524 to 129.

4. "Shale, 205 feet." (Hudson River shale.) From 129 to —76.

5. "Limestone, 330 feet." (Galena and Trenton limestone.) From —76 to —406.

6. "Blue clay, 25 feet." (Shale or clay associated with the St. Peter sandstone.) From —406 to —431.

7. "Sand and some shale, 204 feet." (St. Peter sandstone with, probably, some associated shale below.) From —431 to —635.

The several formations differ but slightly in thickness from the general averages of ten other wells reported from this vicinity two years ago.* In common with two other wells lying north of this one, this boring exhibits a considerable amount of Coal Measure shale in pockets in the Niagara limestone. The overlying Devonian limestone is studded with caverns filled in the same way, and these generally follow joints, which have a north and south trend. From the nature of the filling, which in the uppermost caverns appears to be continuous with the basal sediments of the Coal Measures, it appears evident that these caves must have been tunneled out either during the later part of the Devonian age, when sedimentation in Devonian waters had ceased, or else during the Subcarboniferous age. The distribution of the rocks of this latter age is such as to indicate that, at the time they were laid down, the drainage of this region was from north to south. This coincides with the observed trend of the filled caverns.

Rock Island, Ills. J. A. UDDEN.
Dec. 29, 1897.

PERSONAL AND SCIENTIFIC NEWS.

NEW YORK ACADEMY OF SCIENCES, Section of Geology, Jan. 17, 1898. Meeting opened with a paper by Mr. Arthur Hollick, entitled "Further Notes on Block island; geology and botany."

Mr. Hollick gave a summary of his work done on Block island in July, 1897, and particularly of his success in tracing eastward from Long island the Amboy clays which had previously been determined by palæontological evidence on Staten island, Long island and Martha's Vineyard. Something like fifteen species of Middle Cretaceous flora, nine of them typical of the Amboy clays, have been found. Mr. Hollick then classified the existing flora of the island physiographically into that of the hills, peat bogs, sand dunes and beaches, salt marshes and salt water. In the course of his work he added to the already published lists something like twenty-four new species, although it is not

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*Vide An account of the Palæozoic Rocks, etc., 17th Ann. Rept. U. S. Geol. Surv., P. II, p. 829.

considered that this by any means completes the list of possible species that might be found in the spring. The flora as a whole is distinctly that of a morainal country, and its nearest analogue is that of Montauk point.

Mr. Hollick then offered some suggestions to account for the present peculiar flora of the island, and particularly for the absence of certain species that would be expected, and showed that two features are to be taken into consideration: the geological and the human. Block island is the only part of the terminal moraine along the New England coast which does not have accompanying the moraine a certain amount of plain land, which would naturally allow a variety in the flora. It is presumable that Block island also has been practically separated from the rest of the continent by a deep channel of more than twenty fathoms for a considerable time, and that even before the last depression of land, the island was connected to the mainland merely by a small peninsula, and hence the diversity of the flora as compared with the continent because of the length of separation. The speaker also mentioned extensive archæological discoveries on the west shore of the island, and gave a list of the shells and implements discovered in several of the kitchen middens, and also of the bones of animals brought to light in the old fireplaces in the sand dunes. He made particular mention also of the great number of Littorina, the common periwinkle of Europe which has never before been announced from Block island. The paper was discussed by Prof. Lloyd and Dr. Martin.

The second paper of the evening was by the secretary, entitled "Scientific geography in education."

The speaker brought out the point that geography work may be classified into three divisions: that for the common schools, the secondary schools and the universities, and outlined briefly a few suggestions as to how the subject matter might be treated scientifically in each of the groups, and the dependence of each group upon the others. He paid particular attention to the difficulties of securing scientific work in geography in the grade schools, and to the fact that the present work is extremely unsatisfactory in most of our schools, probably because of the lack of inspiration owing to the neglect of the subject hitherto in universities of the country. The paper was illustrated by exhibition of cheap and easily procurable maps, that may be used for scientific geography work of several grades.

The meeting then closed with a few remarks by the chairman in reference to the famous classic entitled "Lithographiæ Wircenburgensis dacentis lapidum figuratorum, a potiori insectiformium prodigiosis imaginibus exornatæ, specimen primum," written by Dr. Beringer and published in Würtzburg in 1726. Prof. Kemp summarized the work of the author in attempting to explain a great collection of pseudo-fossils from a theological standpoint, the fossils having previously been made by some practical jokers and buried in the rocks for the author to find. RICHARD E. DODGE, *Secretary*.

PROF. WILBUR C. KNIGHT of the University of Wyoming, at Laramie, has been appointed state geologist of Wyoming.

GEOLOGICAL SOCIETY OF WASHINGTON. At the meeting of February 9th, the following papers were presented:

Remarks on the classification of igneous rocks. H. W. Turner.

The Briceville and Wartburg folios. Arthur Keith.
Notes on the Sierra Madre near Monterey, Mexico. R. T. Hill and Bailey Willis.
Some stratigraphic changes in the New River coal fields. W. C. Mendenhall.

At the meeting of Feb. 23rd the following papers were presented:

Tertiary of South Dakota and Nebraska. N. H. Darton.
The origin of the Yosemite valley, California. H. W. Turner.

THE SCIENCE SERIES is the title of a new series of scientific books to be issued by G. P. Putnam's Sons. The series is to be edited by Prof. J. McKeen Catteli, of Columbia University, with the co-operation of Frank Evers Beddard, F. R. S. The following geological volumes are expected among the earlier ones to be issued:

on.

Earth structure. James Geikie.
Volcanoes. T. G. Bonney.
Earthquakes. C. E. Dutton.
Physiography: The forms of the land. W. M. Davis.

MR. J. EDWARD SPURR, who has been spending several months in geological study in Germany and more recently in Paris, sailed for New York the last week in February. Early in the spring he will go to Alaska, under the direction of the United States Geological Survey, to investigate the geology and ore deposits of the Klondike region.

MR. A. D. ROE, of Minneapolis, recording secretary of the Minnesota Academy of Natural Sciences, has been placed in charge of the scientific collections of the Academy and is at present engaged in rearranging the important paleontological and mineralogical collections. He has placed on exhibition in the museum of the Academy a part of his private mineral collection.

PROF. JOHN MILNE has received grant No. 81 from the "Elizabeth Thompson Science Fund." The amount of the grant is $250 and it is given to aid in a seismic survey of the world.

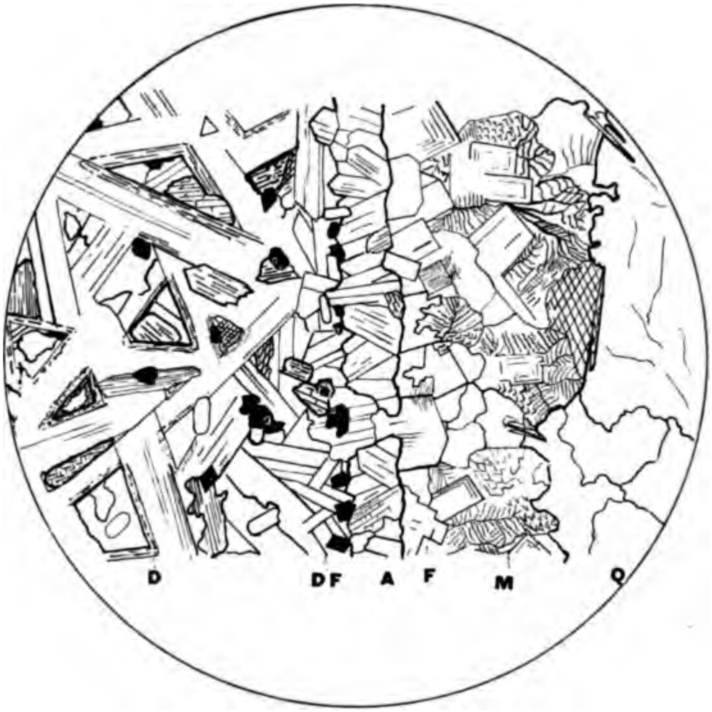

FIG. 1.—Diagrammatic sketch of reaction rim about quartz inclusion, showing secondary pegmatite bands. Enlargement 3 diameters.

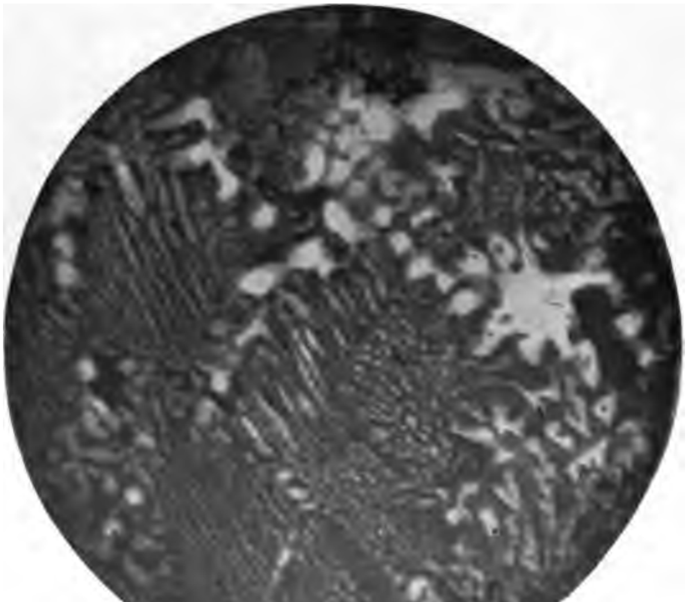

FIG. 2.—Pegmatite. Enlargement 60 diameters.

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AN OCCURRENCE OF ACID PEGMATYTE IN DIABASE.

By T. A. JAGGAR, JR., Cambridge, Mass.

(Plate XIV.)

The presence of quartz and acid feldspar in diabase, as primary constituents, has been frequently described,[*] and the primary nature of the minerals is said to be demonstrated by granophyric intergrowths of quartz with feldspar,[†] and by the occurrence of quartz in idiomorphic phenocrysts.[‡] Törnebohm's Swedish type[§] is described as containing, in the interspaces of the plagioclose laths, an intergrowth like graphic granite, consisting of parallel groups of quartz needles in colorless feldspar. Rosenbusch[||] has mentioned the remarkable abundance of this so-called Konga type of diabase, occurring in many parts of the world, characterized invariably by "quartz-feldspar aggregates in most delicate granophyric intergrowth, such as is observed elsewhere only in granite-porphyry and quartz-porphyry." Rosenbusch states, however, that the discrimination of primary and secondary quartz is very difficult, and that, in diabase, it is more frequently secondary.

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[*] Zirkel, Lehrbach der Petrographie, 1894, p. 631.

[†] Rosenbusch, Mikros. Physiographie, 1896, vol. II, p. 1111.
Zirkel, loc, cit.
Harker, Petrology for Students, 1895, pp. 109-110.

[‡] Zirkel, loc. cit.

[§] N. Jahrb. f. Min., 1887, p. 258.

[||] Op. cit., p. 1144.

The writer has recently studied in detail the fragmental inclusions contained in many of the dikes of the Boston basin. Such inclusions of mineral substance, foreign to the matrix in which they are now embedded, frequently serve as excellent data for recording differential movement or process, affording a unit for comparison of the effects of secondary action which might otherwise be unrecorded in a homogeneous eruptive mass. The evidence, from inclusions, for the secondary origin of the micropegmatyte in the Medford "quartz-diabase" forms the subject of the present paper.

The Medford diabase has been described by Wadsworth,* Crosby,† Hobbs‡ and Merrill.§ The rock extends as a broad dike from Somerville, northeast of Boston, Mass., through Medford, the next township to the north, for a distance of over three miles. In Medford it appears as a dike of width varying up to a maximum of several hundred feet about the old Powder house; further south, in Somerville, the rock occurs again, immediately in the strike of the Medford dike, but of unknown form or extent to the southeast; in this direction it is found again on Granite street in Somerville, not, however, in the Medford trend and again of unknown boundary. In Somerville the diabase is intrusive through the compact pelyte which forms the chief northern member of the Boston basin sedimentaries; to the north the dike cuts the older complex of granite, dioryte, quartzyte and felsitic flows and tuffs.

Hobbs has described this rock as a diabase with an augite-porphyrite facies; the latter occurs only in the outcrops about the Powder house and Willow avenue. Coarse ophitic andesine feldspars, with the triangular interspaces filled with augite, biotite, large apatite crystals, the ores and a host of secondary minerals make up the normal diabase. The specimens of the porphyrite facies from Willow avenue which we have studied differ from the description given by Hobbs in the large proportion of [illegible] and the absence of recognizable augite. The [illegible] large deep brown.

[illegible]

[illegible] Proc. Bost. Soc. Nat. [illegible]

[illegible]

idiomorphic crystals; the biotite shows idiomorphic hexagonal basal sections, in some cases with a beautiful sagenite web. The long magnetite crystal groups, resembling single straight prisms, mostly on the border of chloritized hornblende, are remarkable; they have frequently a length of from 0.75 to 1.0 mm. and suggest the paramorphic resorption borders of the hornblende crystals in trachytes and andesytes, but in this case they never completely surround a crystal, and also occur frequently in long needles between the feldspar laths; in one case one of these long ore needles was seen to intersect a large apatite crystal. Pyrite occurs, and secondary infiltrations of quartz, epidote and idiomorphic calcite occur in irregularly bounded masses in the thin section, stringing out into fissure fillings among the larger minerals. The feldspars are more basic than in the diabase facies, giving in one case symmetrical extinction 19° and 12° in the zone normal to M; this would make the feldspar near to $Ab_1 An_1$, an acid labradorite .

We have thus three facies of this rock in Somerville.

(1) Augite—biotite—andesine diabase.
(2) Hornblende—augite—labradorite dioryte (Hobbs).
(3) Hornblende—biotite—acid labradorite dioryte.

In addition a drusy quartz-microcline pegmatite is a common feature in the Granite street and Pine hill (Medford) localities; this occurs in irregular lenticular or vein-like masses merging into the normal diabase by gradual transitions. Approaching one of these veins, the long white plagioclase crystals of the diabase are seen to acquire a salmon-colored border zone of more acid feldspar; gradually the plagioclase gives place to microcline and the long laths are replaced by short rectangular pink prisms; quartz replaces all the bisilicates and in places the rock appears like a granite; in the open druses prismatic milky vein quartz overlying short, well-formed microcline crystals, with in some places a green amphibole and considerable calcite, stand out on the walls, having all the appearance of infiltration products. Webster, in 1825, noted the presence of quartz and a granitic feldspar as abnormal, saying "in some parts of the bed the feldspar predominates and has a fine flesh color; in one place the prisms of feldspar are an inch or more in length, and cross each other in all directions, leaving angular spaces * * * which contain,

rarely, distinct crystals of quartz. * * * The sienitic greenstone" (pegmatyte) "is crossed in various directions by fissures, the walls of some of which are encrusted with thin layers of feldspar: others are filled up with this mineral."*

These fine veins of microcline and quartz are abundant on the west wall of the Granite street quarry near its northwest corner, where occurs also a large mass about six feet in width of coarse drusy rock, showing long feldspar laths an inch or more in length, usually with a triangular arrangement, the interspaces being filled with quartz and chloritic substance. The contact of this mass with the finer grained diabase is quite sharply marked in sinuous curves; in the diabase dark mica and pink feldspar are very abundantly developed near the contact. This mass seems to have been a more coarsely crystalline gabbroid segregation in the original diabase, in which the coarser quality of the miarolytic pores permitted infiltration of the pegmatyte-forming fluids more freely. The drusy cavities now developed by weathering are frequently from one to two inches in length, and contain crystals of microcline feldspar, quartz and amphibole.

Similar drusy openings are found in the pegmatyte veins which penetrate the normal diabase; and the walls of these veins are not sharply marked, for we find the feldspars of the diabase kaolinized and salmon-colored in the zone next to the pegmatyte, showing by their wavy extinctions in thin section an acid border on the side next to the triangular interspaces. Still nearer to the vein the ophitic structure of the diabase gives place to the development of plump squarish microcline crystals irregularly distributed, with occasional quartz. A series of three thin sections, made from a single specimen of the rock at distances of 10 cm., 4 cm., and 0 cm. from a quartz-microcline druse, shows the transition from the normal diabase structure through the "quartz-diabase" phase to a normal vein pegmatyte. In some cases the "quartz-diabase" zone is much wider, the rock showing for several feet a considerable amount of interstitial quartz, always, however, accompanied by more or less of the salmon-colored feldspar. In these localities there is no immediate evidence, in either the hand

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*Boston Journal of Philosophy and Arts, 1825, vol. II, p. 277; and vol. III, p. 486.

specimen or the thin section, of the secondary nature of the quartz.

Large inclusions of quartz, of irregular clastic form, are common in the Pine hill and Granite street outcrops. These fragments vary in size from a few inches to a foot or more in diameter; they frequently have a faint rose color; in some cases they are coarse vein quartz, in others quartzyte. They have not been found by the writer in the dioryte facies of the rock which occurs in the vicinity of the Powder house. These inclusions are frequently rounded and sometimes embayed by magmatic corrosion; one of these is now well displayed on the west wall of the Granite street quarry, measuring twelve by three inches, with rounded contours bounded by the wreath of augite prisms characteristic of quartz inclusions in basalt,* and with a narrow-necked embayment at one end three inches in depth.

The augite wreath, or more accurately, mantle, invariably encases these inclusions, forming in the thin section an endomorphic "reaction rim" in the diabase at the contact of the inclusion. This mantle varies with the association in the diabase; if in association with the quartz-pegmatytes the rim is wide, showing successive zones from the diabase to the inclusion of augite, microcline, micropegmatyte and chlorite; if in the normal diabase the rim is a simple border of augite prisms.

Thin sections (52-53) from the contact of a large quartz inclusion in the normal diabase at Granite street show coarse ophitic structure in the diabase, with biotite, augite and some brown hornblende. The quartz of the inclusion is clear, consisting of very large interlocking grains which show strain, with numerous liquid inclusions in lines; it is apparently vein or pegmatyte quartz. The border outline of the quartz appears corroded and irregular, with long prisms of a green amphibole and chlorite penetrating it in places, and abundant calcite. Between this border and the diabase, closely packed augite prisms form a continuous zone, idiomorphically terminated on the diabase side, their bases on the inclusion side

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*Dannenberg, A.—Tschermaks Min. u. Pet. Mitth., 1894, Bd. XIV, p. 17.

Lacroix, A. Les enclaves des roches volcaniques, 1893, p. 585.

Vide also Rosenbusch, p. 1034. Zirkel, vol. II, p. 871; vol. III, p. 102.

a mass of chlorite and calcite. Chlorite is the chief secondary product from the augite, filling all the cleavage cracks. The hornblende and feldspar of the diabase are allotriomorphic to the augite rim, while the ores and apatite are of earlier generation.

Two other quartz inclusions [illegible] from the northern wall of the [illegible] street quarry, where the rock is filled with a net-work of the salmon-colored quartz-tourmaline veinlets and the diabase is full of interstitial quartz, show a remarkable modification of their pyroxenic mantle. In the hand-specimen the quartz has a faint rose tinge in one case, in the other it is turbid with inclusions. The zone of alteration in the diabase is from seven to fourteen millimetres wide. In the case of the smaller specimen the inclusion has broken out of its gray matrix, bounded by the outer layer of this alteration zone which forms over it a smooth rounded scaly coating of greenish-black color.

A thin section of this reaction rim shows to the naked eye an outer layer of augite prisms arranged mostly with their prismatic axes normal to the original inclusion surface, and with idiomorphic terminations on the diabase side. Their basal terminations form in section a continuous flowing line, which as will be seen later represents the original surface of attachment. On the opposite side of this line, that is, developed towards the quartz inclusion, on the inner side of the outer augite band, is a line of squarish grey feldspar prisms. On the inner surface of this zone is a thin green line of chloritic alteration, well defined, and within that sometimes a second feldspar band is seen, but not continuous.

[illegible] thin section may be [illegible] DE. A [illegible] the quartz [illegible] order, is as [illegible]

[illegible] section, two [illegible] diabase, [illegible] enclosing [illegible] fragments [illegible] ives and [illegible] Michel [illegible] determined

for a crystal near the periphery of the section on the side remote from the inclusion; the extinctions were lower at a point (the only one in the slide, see figure 1) where the augite zone is interrupted, and a feldspar half penetrates within the zone, coming into immediate contact with an acid feldspar of the inner zone; this crystal showed a more acid composition, near the andesine group. The feldspars occupy, in the thin section, an area greater than all the other minerals of the diabase taken together. The feldspar extinctions are frequently wavy, and the mineral is kaolinized only about the border of the triangular interspaces. The rock is otherwise quite fresh, and the other minerals are distributed in characteristic ophitic fashion; the triangular interspaces among the feldspars are filled with augite and secondary uralite, with magnetite, ilmenite and leucoxene, biotite and secondary chlorite, large apatite crystals and some calcite. In the hand-specimen biotite is quite abundant in flakes two or three millimetres in diameter.

ZONE OF DIABASE FELDSPAR (DF,). Next to the band of augites, the feldspars of the diabase form a confused mass of finer texture than in the normal rock; they form a zone, averaging one millimetre in width, of short rectangular prisms, allotriomorphic to the distal terminations of the next inner zone of augite prisms. Scattered magnetite and apatite crystals, the only other minerals in this band of small basic feldspars, are most abundant along the irregular contact line of the augites, interpenetrating both these and the feldspars, and hence of earlier generation than either.

ZONE OF AUGITE CRYSTALS. (A). This corresponds in all respects with the normal augite wreath of quartz inclusions (see preceding page). The outer border of the augites is very irregular and appears to be the terminations of a crowded row of prisms of varied length, attached on the inner or (relative to the inclusion) proximal side to a smooth and gently sinuous surface, their terminations forming on that side an uninterrupted contour in section. The general arrangement of the prisms is in clusters radiating from the convexities of the surface of attachment. The idiomorphic distal terminations represent the usual pyramid faces (111), and between crossed nicols occasional twinning is seen, parallel to

(100). The dichroism mentioned by Hobbs* as characteristic of the augite of the diabase could not be detected in these bands. The chief alteration product on the cleavage cracks is chlorite: in several places a deep green amphibole was also observed, in well marked basal sections, and without fibrous structure. It seems probable that the formation of this mineral was associated with the same process that produced the inner zones, next to be described.

THE ZONE OF POTASH FELDSPARS. (F.) Next to the augite wreath, on the inner side, is a row of squarish crystals of microcline, developed base to base with the prisms of the augite zone, in bunches idiomorphically terminated on the proximal side. (See figure 1.) In two cases the characteristic microcline twinning is very plainly shown, though as the section is cut transverse to the surface on which the crystals developed, the basal section, which would show plainly the grating structure, is rare. The M sections are common, and in one case the extinction is 5°, with no twinning visible. The section nearest to the basal gives an extinction of 12° on one lamella of the albite twinning and about 17° on the other: the pericline lamellæ are indistinct and show that the section is obliquely oriented, but the grating-structure is typical. Furthermore, these feldspars are very largely kaolinized, the opaque portions showing in reflected light the characteristic salmon color.

THE ZONE OF MICROPEGMATITE. (M.) Within this band of microcline is a zone of varying width consisting of quartz individuals filled with a very remarkable micropegmatyte intergrowth with the kaolinized feldspar: the latter forms feather and fern-like structures of most delicate and intricate patterns, sometimes anastomosing, sometimes enclosing minute triangular portions of the quartz, and in other cases with the usual micrographic habit. A portion of this structure is shown in the accompanying microphotograph (figure 2) magnified 60 diameters, in ordinary light: the light portions are quartz, the dark are kaolinized feldspar.

In association with this, and nearer the quartz border, calcite and chlorite are abundant, the latter sending long fibrous bundles into the crevices of the quartz [illegible] the border of

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*Op. cit., p. 6

which is corroded and embayed. The quartz inclusion is made up of large interlocking individual grains of varying size.

Summarizing the description of the cross-section of the reaction rim about the inclusion, we have an outer zone of augite prisms as is usual about quartz inclusions in basalt, and as in most cases in this diabase. But within this is a zone of quartz-microcline pegmatyte, of exactly the same nature as that which fills the cavities in the adjoining rock; and the microcline is developed as a zone of prisms on the inner surface of the old augite zone while the border of the quartz inclusion is corroded,—phenomena that can be accounted for only on the hypothesis that the waters or vapors charged with the pegmatyte minerals forced their way through the pores of the old augite zone, which was not chemically affected by them. The quartz inclusion they corroded, however, and simultaneously microcline was deposited on the inner surface of the augite mantle, and last of all the micropegmatyte mixture.

An inner zone of acid feldspar about a quartz inclusion has been described by Dannenberg* in basalts of the Siebengebirge, and his succession of zones closely resembles that of the Medford diabase. He notes next within the augite zone a band of large fan-shaped bundles of feldspars of higher acidity than the feldspar of the basalt, but he does not state whether these are developed radial to the inner surface of the augite mantle or to the quartz surface. He notes an inner or second augite zone with prevalent skeletal structures; this we have also observed occasionally.

Mention was made in a preceding paragraph of the infiltration minerals observed in the thin section of the diorite facies of the rock. Merrill† has called attention to the extraordinary depth to which the post-glacial disintegration of this rock has gone, largely due "to its coarse and somewhat granular structure;" it is highly miarolytic, the ophitic framework of feldspars forms a sort of "sponge" support when much degeneration has gone on in the interspaces. Just as such a

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*Danneberg, A., Studien an Einschlüssen in den Vulkanischen Gesteinen des Siebengebirges, Tschermaks Min. u. Pet. Mittheilungen, 1894, Bd. XIV, p. 17.

†Bull. Geol. Soc. Amer., vol. VII, pp. 349-362. 1896.

structure permits deep penetration of waters from the surface, so it affords easy passage to heated "mineralizers" from below, and the evidence from the pegmatytes in question shows distinctly that they were formed by secondary infiltration.

If this be true of the case in question, however, we should expect to find similar pegmatyte dikes cutting rocks in the vicinity other than the diabase. Such evidence is not wanting; three miles to the westward the long ridge of Arlington heights, extending to the southward, is composed chiefly of a coarse hornblende-biotite-diortyte associated with an ancient amphibolite gneiss. Outcrops of the gneiss occur just west of the southern end of this ridge at Owl hill, and at numerous points along its flanks, notably in the region immediately adjacent to Spy pond on the northwest Here the gneiss is interbedded with black calcareous strata and the whole series strikes northeast with a northwest dip of 40°. Intrusions of granite interrupt the gneissic rocks, appearing in one place like an irregular interbedded sheet or laccolyte; the gneiss is seen to dip directly under a granite mass. Cutting both the gneiss and the granite are pegmatyte dikes of coarse, granular quartz and large salmon-colored microcline crystals. Transverse to the plane of the wall, one of these dikes showed a remarkable parting, similar to columnar structure, in the quartz; the quartz could be broken out in rectangular blocks. As there is much evidence from thin sections that all of these rocks have been violently strained dynamically, it is probable that this jointage in the vein is due to pressure. These pegmatytes, of which several dikes were found, trend east and west as do also the basic dikes observed in the same vicinity. Minute veinlets of epidote occur in the pegmatyte, and epidote occurs in large idiomorphic crystals in both the granite of Arlington and the dioryte of Owl hill, conspicuously in the latter.

These granites and diorytes are usually believed to be very ancient rocks, and so indeed they may be. The pegmatyte dikes cutting them, however, are identical in composition and microscopical structures with those cutting the Medford diabase, and the two sets are believed by the writer to be of contemporaneous origin. That this period followed closely on the intrusion of the granites is not probable in this case, and

we do not believe that these pegmatytes bear the same relation to the granite that is usually attributed to the aplyte and lamprophyre dikes which represent the last differentiation products of the granite magma. The word "dike" here used for these pegmatytes is perhaps inaccurate if used in the genetic sense of an igneous intrusion. The pegmatytes cutting the gneiss are more like quartz-feldspar "veins," varying from a few inches to two feet in width, sometimes drusy, showing idiomorphic terminations to the crystals in open cavities, sometimes an aggregate of granular quartz with very little of the feldspar. Elsewhere the "graphic granite" structure predominates. Were it not for these feldspathic intergrowths, the word "vein" would both here and in the intrusions in the diabase seem more appropriate. In both cases it is believed that the deposits were made from super-heated waters under pressure, which took into solution from the rocks through which they passed (probably largely granite) the necessary mineral matter. The period at which this took place was after the consolidation of the Medford diabase intrusions, probably post-Mesozoic. This is proven by the zonar growth of the feldspars of the so-called quartz-diabase, by the pegmatyte veinlets and by the secondary pegmatyte bands surrounding the quartz inclusions. We thus conclude that granophyric intergrowth of quartz and feldspar in a diabase is not necessarily evidence of the primary nature of these minerals.

THE GEOLOGY OF THE ENVIRONS OF TAMMERFORS.

By J. J. SEDERHOLM.

[Translated from the Guide to the excursions of the Seventh International Congress of Geologists.]

The Archean rocks of the environs of Tammerfors can be divided into three parts which are as follows from above downward.

1. Post-Bothnian granite.
2. Bothnian schists.
3. Pre-Bothnian terrane of gneiss.

In the last, granites, which are essentially metamorphic, prevail, in part porphyroids, and foliated gneisses which are

granetised mica schists, folded to the highest degree. There are also typical mica schists, and, in the granites, inclusions of dioryte and peridotyte.

All these rocks appear at the south of the city of Tammerfors in a belt, sometimes having the width of 40-60 kilometres, extending toward the west to the gulf of Bothnia, and toward the east beyond the lake Päijänne. The same formation is also very extensive in other parts of the country.

To the north from this belt of strongly metamorphic rocks come in the schists of Tammerfors, or Bothnian formations. They are in bands extending from west to east and generally following the borders of the gneiss formation and the great area of post-Bothnian granite which extends from the gneisses toward the north covering an area of more than 23,000 square kilometres. The layers of these schists are always nearly vertical.

These schists are remarkable for their character, which is at once crystalline and completely detrital. They are often represented by typical phyllytes which sometimes approach argillytes and sometimes pass into fine-grained mica schists, often containing feldspar. In this case they present a gneissic character.

The phyllytes of Näsijärvi show, by their very distinct stratification and their internal structure, that they are a formation of shale in a metamorphic state, intercalated with thin beds of an argillaceous sandstone (leptitic phyllyte). The phyllytes often contain a carbonaceous substance, sometimes accumulated in thin bands, the outlines of which suggest an organic origin.

A very typical leptyte, of a reddish color and poor in mica (always black mica), appears in a small area west from Tammerfors. It shows a distinct alternation of beds originally horizontal, and of layers which possess an oblique stratification.

Dark green schists, rich in amphibole (and most frequently in uralite), and in plagioclase which constitutes porphyritic crystals, are almost as widely extended as the phyllytes. These rocks, called porphyroids, are metamorphic tuffs of Archean effusive rocks. In them are sometimes seen intercalated beds of true eruptive rocks, notably uralite porphyrytes and plagio-

clase and orthoclase porphyrytes, which in their original state were identical with basalts and andesytes and with modern trachytes. A similar porphyritic rock also crosses the phyllytes in dikes.

The conglomerates with a crystalline cement are, however, the ones which among the Bothnian rocks afford the highest interest. They consist of interbedded portions, and here they are of greater amount than in any other system equally old.

They can be studied best on the shores of lake Näsijärvi, and especially in the little bay of Hormistonlahti, where can be seen four vertical layers whose thicknesses are, respectively, 1-2 metres, 200-300 metres, and 20 metres. They can be followed toward the east for more than 30 kilometres. Westward from Näsijärvi they recur for a distance of 4 kilometres in the parish of Ylöjärvi, and always at the same geological horizon.

The pebbles of this Archean conglomerate are very variable as to size, the largest having a diameter of half a metre, and the smallest being microscopic. They are generally well rounded, and of different forms, according to their petrographic nature. The greater part consist of different prophyritic effusions, and of porphyroids, phyllyte and leptyte, all these rocks outcropping immediately to the south of the conglomerate. But there are found also two varieties of granite or quartziferous syenyte, and a quartziferous dioryte.

The cement of the conglomerate is crystalline, but under the microscope it shows an originally clastic character. It is composed of minute fragments of the same rocks which form the pebbles, mixed with fragments of plagioclase, uralitized augite, olivine changed to biotite, etc., and of secondary minerals, especially of feldspar, quartz and biotite. The beds of conglomerate alternate with a dark-green schist very rich in uralite, which is a metamorphic tuff of a basic effusive rock. All these beds are vertical.

North from these beds of conglomerate are found, on point Kämeeniemi, a new conglomeratic bed, with a thickness of 20 metres. If this bed, as well as the tuffs and phyllytes that appear toward the north, were originally superposed conformably upon the rocks which outcrop to the south from

Hormistonlahti, the total thickness of the formation of the schists of Tammerfors is at least from four to five thousand metres (2,000 metres of phyllytes, 1,500 metres of the lower tuffs, and of the conglomeratic zone, and the remainder upper tuffs, with their intercalations of phyllyte and conglomerate). The order of this enumeration is also that of their stratigraphic succession, the phyllyte always outcropping alongside of the gneisses which supported it formerly, and these last south of the schists.

The great contrast between the straight stratification of the phyllytes and the intense folding of the gneiss warrants the presumption of a great hiatus between these formations. Indeed, at several points, as at the north of Aittolahti, can be seen dikes of granite which are abundant in the gneiss, which never cross the phyllytes. There can be seen, in the neighborhood of the contact line, only small masses of porphyritic granite introduced in a solid state during the folding of the phyllytes, but never anything that can be interpreted as an injection of this rock when in the condition of a magma.

In the region to the east from Näsijärvi, north from Siuro and in the country west of Päijänne, can be seen the clear contact between the phyllytes and the porphyroidal granite. It is there easy to see that the granite has served as a base for the metamorphosed sediments which constitute the formation of the schists of Tammerfors.

The granite which outcrops north of the schists shows always contact phenomena that indicate its more recent date. It cuts the schists in numerous dikes, and the manner of penetration is so intimate that over several hundreds of metres the contact rock can be called gneiss in the form of dikes or granitized schist. One can very easily study the origination of such a rock on the west shore of the Näsijärvi, at the northern contact of the outcrop of the schists of Tammerfors. On the eastern shore, where can be seen analogous phenomena, the porphyroid, rich in uralite, appears to be converted into a massive rock resembling a dioryte. In another contact zone, at Orihvesi, the schists are changed, for a distance of more than a kilometre from the line of contact, into a schistose rock resembling a leptynyte rich in feldspar, which appears to have crystallized under the influence of the surrounding granite.

This granite also shows a zone of endogenous contact, in the form of a structure at once porphyritic and evidently micropegmatitic, although in part concealed by the metamorphism which the rock has suffered since consolidation.

The granite contains, at several points, elongated bands of schists, and everywhere very numerous fragments. These inclosures are in general strongly granitized, and in that case they have the structure of a dike gneiss ("gneiss à filons"), or of a dioryte. But these enclosures show also, here and there, the structure and the mineralogic composition of the schists of Tammerfors, and contain sometimes undoubted pebbles, which are incontestable proof of the sedimentary origin of the enclosed fragments. Quite often, as for example, north of Teiskola, these enclosures have an aspect of a true dioryte, though of a variable structure.

The schists which outcrop in the parishes of Suodenniemi and Lavia at the west of Tammerfors are in part more metamorphosed than those of which we have just spoken. Phyllyte is here often replaced by mica schist which only differs very little in its petrographic composition from the mica schists of the underlying formation. Here also is a conglomerate which has almost the aspect of a gneiss spotted with amphibole. At Harju, in the parish of Suodenniemi, is another very interesting conglomerate, on account of its almost gneissic structure. On the surface which is attacked by the atmosphere, the contours of the pebbles and their rounded forms appear very distinctly, but in the hand specimens, and especially in thin sections, their limits are confused in consequence of the presence of numerous secondary minerals. Everywhere one can recognize among the pebbles representatives of some of the rocks that occur in the underlying gneiss, among others of the "gneiss of Lavia." This porphyroidal schistose rock recalls, when it is well preserved, a tuff or a porphyritic effusive rock which by a profound metamorphism has been made to take the aspect of a gneiss.

It is very interesting to see here the most positive demonstration of a discordance between the Bothnian schists of Lavia and the mica schists of the underlying formation which possess almost the same petrographic characters. At Lavia, indeed, can be seen the clear contact of the granite cutting the

schists of the gneissic terrane with the schists of Lavia. In the contact zone the granite presents the character of a breccia which near the schists, assumes the aspect of a basal conglomerate. Evidently the surface of the granite was disintegrated by atmospheric action before the deposition of the sediments which in a metamorphic condition, form now the schists of Lavia and of Tammerfors. The same phenomenon is repeated at several places in the same region, though in conditions less typical.

The mass of the schists in the west of Finland formed, like the schists of the region of Tammerfors, in the interval between the two great Archean epochs of granitic irruption in those countries, has received the name of the "Bothnian formations." To this series of rocks belong also the uralitic porphyrytes of Tammela and of Kalvola at the west of Tavestehus, and of Pellinge near Borgo. The effusive character of those Archean rocks, accompanied by tuffs, cannot be mistaken. Further one can also refer here probably the schists which outcrop at Ylivieska, in the government of Uléaborg, and perhaps also several formations in northern Sweden. All these schists, whose layers are always almost vertical, abound in intercalations of conglomerates.

Again, in the neighboring portions of the coast of the gulf of Finland, where the land is composed of Archean rocks of a different age, dislocated at the same epoch and intimately penetrated by post-Bothnian granites, can be found, at several places, debris of Bothnian rocks the original composition of which is sufficiently preserved to be recognized.

All this country having thus undergone intense dislocations at an epoch later than the deposition of the Bothnian beds, it is not possible to doubt their pre-Cambrian age, especially if one takes into consideration that the beds of Cambrian and Silurian rocks of Esthonia, on the opposite shore, south of the same gulf, are almost horizontal. It is to be remarked also that the pre-Cambrian sandstones of Björneborg and of Kauhajoki, and the granito-porphyritic rocks called "rapakivi" which occur in very extensive "massifs" in the south of Finland, do not show any sign of metamorphism.

The pre-Cambrian age of the rocks mentioned being proved by the fact that they have been recognized in the form

of pebbles in the basal fossiliferous conglomerate of the Cambrian, it is plain that the folding in this region was terminated long before the Cambrian period.

But the age of the Bothnian schists seems to be susceptible of a still more exact determination. In the eastern portion of Finland is a series of folded sediments more ancient than the "rapakivi," but more recent than the Archean granites of the type of those which cut the schists of Tammerfors. Hence the latter are separated from the base of the paleozoic group by two great formations (of the systemic rank) and three immense discordances.

They are, further, so intimately allied to the fundamental crystalline complex, called Archean, of the south of Finland, that it is absolutely impossible to hope to separate them from it. Therefore, their presence at several points is not at all surprising to those who have made investigations on this terrane of such rocks, existing at other places. In all cases the formation of Tammerfors is such that the sedimentary and the metamorphic nature of the true Archean schists is shown with the most complete evidence.

NOTE ON TRELLISED DRAINAGE IN THE ADIRONDACKS.

By Albert Perry Brigham, Hamilton, N. Y.

(Plate XV.)

This brief paper may serve to suggest a problem in Adirondack drainage. In the study of the new topographic maps of eastern New York attention was attracted to a marked adjustment of drainage in the region covered by the central and western part of the Elizabethtown sheet and the eastern part of the Mt. Marcy sheet. The district, as limited in the accompanying sketch map (plate XV) traced from the sheets, extends fourteen miles from east to west and eleven miles from north to south. Its eastern edge is from five to seven miles west of lake Champlain and its western edge is four and one-half miles from the summit of Mt. Marcy, the highest of the Adirondack peaks. In the central and southeastern part of the district the summits commonly range between 1,500

and 2,000 feet in altitude. Farther north and west the higher mountain mass is attained, and several summits exceed 4,000, or even approach 5,000 feet.. It is an area of bold mountains and deep valleys, with a steep general slope to the southeast. The range of relief is from Dix Mt. 4,842 feet, to the exit of the Boquet river, at about 625 feet. The mountain ridges trend northeast by southwest and are seven or eight in number, alternating with the principal valleys. Many subordinate valleys cross these ridges at right angles, thus dissecting the mass in a marked fashion into rectangular blocks. The drainage of most of the area, and that chiefly concerned, is divided between the Boquet river on the north and the Schroon and its branches on the south. A corner at the northwest lies in the basin of the Ausable, and a narrow strip on the east drains into lake George.

The trellised arrangement of streams and valleys is explained and the general principles are quite fully illustrated by Prof. Davis, in his account of "The Rivers and Valleys of Pennsylvania."* Willis, in his monograph on the northern Appalachians, treats the subject briefly and gives a suggestive sketch map.† Several atlas sheets of the Pennsylvania topographic map may also be consulted in this connection.‡ The conditions apparently essential for such arrangements are a series of anticlinal and synclinal folds of alternating hard and soft beds, with rising and falling axes. These conditions are met whenever, over a considerable area, a normal series of sedimentary beds is subjected to moderate folding. Lateral migration along the soft outcrops, and capture by favorably situated streams, will then produce the grapevine system. The master streams may follow the axes after mature adjustment, or in case of antecedent streams, or revival with different attitude, they may cross the axes of folding.

Almost no study has been given to Adirondack drainage. The direction of the mountain ridges is noted by Emmons and others, and indeed is suggested by the alignment of the lakes, upon an ordinary map. The most complete account

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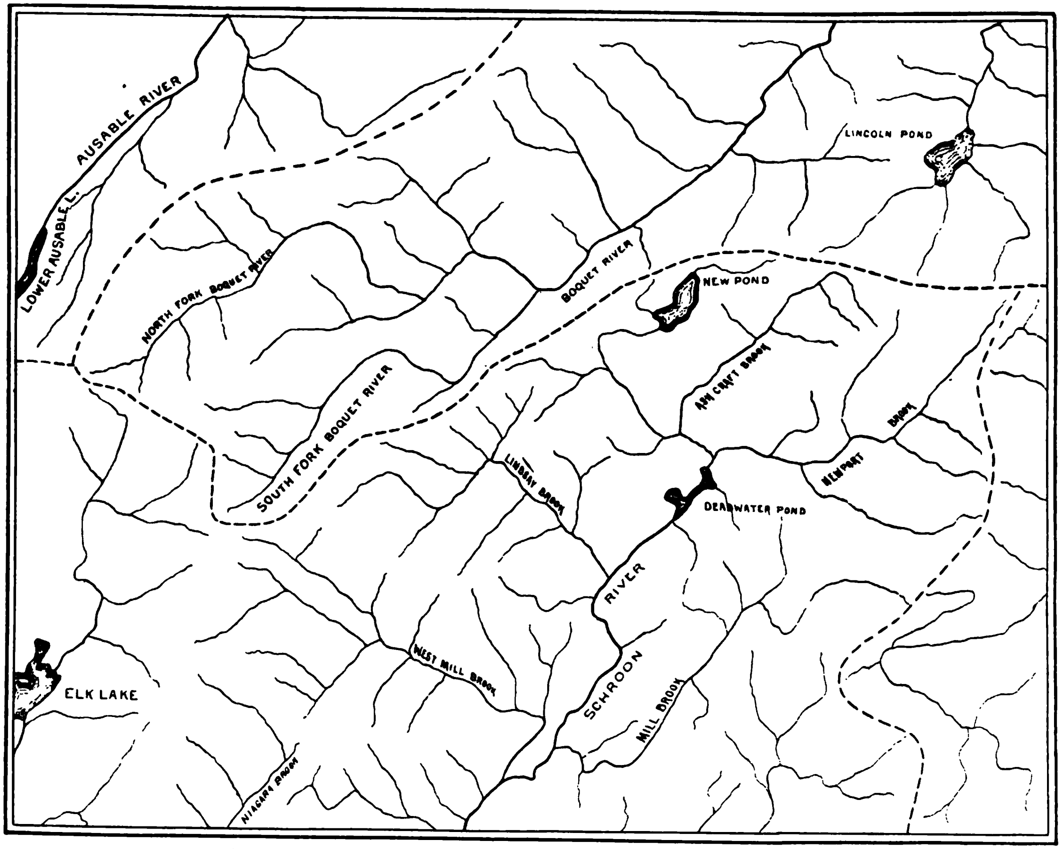
*National Geog. Mag., vol. I, pp. 206-219.

†National Geog. Monographs, pp. 185-187.

‡Prof. R. E. Dodge, of the Teachers' College, New York, has brought out this drainage system very effectively for class-room use by mounting a group of sheets and tracing the streams in heavy lines.



Adirondack Drainage in Essex County, New York.

of the geology of this part of the Adirondacks is by Prof. Kemp,* who, in his introduction, gives an outline of the topography and supports with a number of considerations the view that the valleys are mainly due to the faults and that the mountain ridges are of the block-tilted type, though this is affirmed to be less readily demonstrable in massive and metamorphic rocks. This increases the interest and the perplexity of the problem, and will make the more welcome to physiographers the structural facts which Prof. Kemp and others are working out in the Adirondack region. The drainage is also very ancient, hence through oscillation and the baselevelling processes there may have been several opportunities for new adjustments, but through all it would appear that the original streams consequent on folds or faults of northeast by southwest trend have transmitted their axial direction to their successors. If the region has ever been baselevelled and the drainage revived, the elevation was not accompanied by tilting of such a nature as to send the master streams across the great structural lines. All goes to emphasize the suggestion of Prof. Davis that "every case must therefore be examined for itself before the kind of re-arrangement that may be expected, or that may have already taken place, can be discovered."

It remains to note a few features shown by the sketch map. The south fork of the Boquet river, flowing northeast, makes two distinct elbow turns, first to the southeast and then resumes its original direction to the northeast, in the main valley. The extreme head waters of Lindsay brook show a tendency to open up the Boquet valley farther to the southeast. The north fork of the Boquet occupies another parallel valley two miles northwest of the south fork. This stream makes three elbows, first to a valley in line with south fork, then to the main valley. In the case both of the Boquet and the Schroon, tributaries flowing to the southeast are conspicuously longer than those flowing northwest. This is readily explained by the steep southeastward inclination of the country and the consequent rapid headward cutting of the tributaries flowing from the northwest. Similar features in

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*Preliminary report on the geology of Essex county. 47th Report New York State Museum, 1894.

the Schroon drainage will be readily suggested by inspection of the map. The sharp elbows and rectangular blocks are even more conspicuous upon the contoured sheet than in the accompanying map. The valley of New pond is practically continuous with that occupied by the upper transverse tributaries of Lindsay and West Mill brooks, and with the valley of Niagara brook. In a similar way the valley of Ash Craft brook continues southwest to Lindsay brook. Mill brook and Newport brook show a similar alignment with each other. It is quite possible that the Boquet has robbed some territory from the Schroon, because of its much more rapid descent and much shorter distance to the baselevel.

If the northeast southwest valleys are due to faulting, the long, intervening mountain blocks may have been cut up into short rectangles chiefly by the northwest heading of transverse streams as above described. This work seems to have diverted and checked the growth of some streams along the great structural lines. Old as the region is, adjustment appears to be by no means complete.

SOME RESEMBLANCES BETWEEN THE ARCHEAN OF MINNESOTA AND OF FINLAND.*

By N. H. WINCHELL, Minneapolis.

In several of the reports of the Minnesota Survey some characters of the Archean have been described which have appeared to be unique, since they have not been mentioned elsewhere in the lake Superior region. The non-observance of these characters by other geologists has rendered it necessary to be cautious in drawing final conclusions as to their origin and significance. Hence some of the interesting localities have been examined several times, and additional details and sometimes new interpretations and new facts bearing on the genesis and succession of some of the parts of the Archean have been derived from these later visits.

It was during the latter part of the summer of 1897 that

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*Read before the Minnesota Academy of Natural Sciences, Dec. 30th, 1897.

some of the most important observations were made.* Without attempting here to give *in extenso* the evidence of the conclusions arrived at, the following general scheme will show the Archean formations which exist in the northeastern part of the state and their order from above downward, according to all the facts now at hand. These parts are represented by hundreds of specimens collected, and by hundreds of microscopic thin sections.

In descending order:

1. *Granitic intrusion*, cutting and metamorphosing the earlier schists and fragmentals. This granite, though generally massive and having a distinct irruptive contact on the older rocks, is also sometimes gneissic, and the schists vary to a banded gneiss, so that in some cases the transition from the one to the other is screened by these similarities and is hardly noticeable. This rock is seen about Snowbank lake and Moose lake, about the western confines of Disappointment lake and at Kekequabic lake. It is also supposed to constitute the Giant's range. It is a wide-spread, irruptive granite, is coarse-textured and fresh.

2. *Upper Keewatin.* Consists of conglomerate (at Stuntz island and at Saganaga and Ogishke Muncie lakes), sericitic schists, quartzose and also micaceous schists, graywackes, clay slates, chloritic schists and porphyroids. Of these rocks which stand about vertical and are distinctly bedded by sedimentary action, the conglomerates are the most remarkable, for they seem to pervade the formation at different horizons, and by metamorphism they acquire coarse secondary feldspar and hornblende crystals. The whole formation becomes changed, by the widespread effect of the pressure and disturbance coincident with the intrusion of the granite above, into mica schists and banded gneisses, and is penetrated by many granitic dikes. Such mica schists, embracing many conspicuous boulder-forms on the weathered surfaces, are to be seen about Moose lake and between there and Snowbank lake, and on the western shores of Snowbank lake; about Disappointment lake, Kekequabic lake and eastward to Zeta lake. These fragmentals are conspicuously porphyritic by secondary

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*In this trip I was accompanied by Dr. U. S. Grant and by Mr. A. H. Elftman.

feldspars between Moose and Snowbank lakes, and at Zeta lake.

3. *Granitic intrusion.* This intrusion is frequently characterized by fine-grained granites or felsytes, but is chiefly represented by the granite of Saganaga lake, which is frequently very coarse. The Upper Keewatin lies unconformably upon it at Saganaga lake, with a profound erosion interval between, but this granite cuts older greenstones and green schists (No. 4) at West Seagull lake. Such granite is seen at Ely (a little west of the village) in the form of a light-colored felsitic dike or quartz porphyry, which can be traced for a quarter of a mile east and west. It also occurs on the Kawishiwi river. It supplied numerous boulders for the conglomerates seen in the Upper Keewatin.

4. *The Kawishiwin or Lower Keewatin.* This is the oldest known formation in the state,* and is essentially a greenstone formation, in which the rock is both massive and fragmental. When stratified, as it is over large areas, it consists of basic tuffs, agglomerates and green, stratified schists and greenwackes. It contains the banded jaspilytes and iron ores at Vermilion lake. At Moose lake is a jaspilyte iron ore which is at the same time a coarse conglomerate, but it is not certain that this is in the Lower Keewatin. These greenstones, with their attendant schists and jaspilytes and greenwackes, are cut extensively by granite, and by quartz-porphyries, as above mentioned, and are converted to mica schist and banded gneiss, and in that form are very widely extended. There is frequently considerable doubt whether some of the Minnesota areas of gneiss and mica schist (Coutchiching?) belong to the Upper or to the Lower Keewatin.

No account is here taken of the diabase dikes, whether Keweenawan or earlier, which are not uncommon.

Unconformably above all these is the Animikie formation, of the age of the Taconic, the base of the Paleozoic. This formation is tilted but not closely folded. It contains the iron ores of the Mesabi range, as well as those of the Penokee and, when broken and overwhelmed by the Norian, it witnessed another, but less extensive, granitic intrusion.

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*In a former scheme of the structure of the Archean this was put at the top of the Keewatin (20th report, p. 4.) but later field observations have shown it is the oldest known rock terrane of the state.

To recapitulate briefly, the descending order of the parts of the Archean seems to be as follows:

1. Granitic protrusion and extended metamorphism of the clastics.
2. Upper Keewatin. When not metamorphosed these are conglomerates, graywackes and clay slates, sometimes mingled with greenish debris.
3. Granitic intrusion, the intrusive rock being usually fine-grained, but also constituting coarse granite.
4. Lower Keewatin or Kawishiwin, mainly greenstones, both massive and fragmental.

From this it appears that some order is beginning to appear in that ancient group of rocks which for many years geologists have been content to designate simply as Archean or as the fundamental complex.

For a knowledge of the results obtained by similar studies in Finland we are indebted to the Guide-book of the International Congress of Geologists of the seventh session, in which the government geologist, J. J. Sederholm, gives a succinct description.* A condensed statement of the structure and stratification of the Finland Archean, as given by Sederholm, is as follows:†

In descending order:

1. Post-Bothnian granite.
2. Bothnian schists.
3. Pre-Bothnian terrane of gneiss.

At the bottom of the known Archean (No. 3 pre-Bothnian gneiss) there is therefore, as further described by Sederholm, a series essentially gneissic but containing mica schists, and porphyroids. These schists and porphyroids, on the assumption that they are metamorphic fragmentals, imply the existence of some older rocks from which the debris was derived. What the nature of that older rock may have been is not stated definitely by Sederholm, but it is possible to infer from inclusions which he mentions in the granites that pierce these schists that it was a basic rock. Such inclusions are

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*Reference may be made to a letter from Dr. Bascom in the AMERICAN GEOLOGIST, Nov. 1897, p. 339, in which is described the excursion to Finland, with notes on the geology.

†A translation of Sederholm's description of these formations is given in this number of the AMERICAN GEOLOGIST.

tated to consist of dioryte and peridotyte. This pre-Bothnian gneiss and the schists which accompany it are comparable to the gneiss and schists of the Lower Keewatin when crystalline, to which Lawson gave, in part at least, the name Coutchiching, and the intersecting granites when intrusive to the earliest Minnesota granites.

To the north from this belt of strongly metamorphic and highly folded rocks is a great formation which Sederholm has named the schists of Tammerfors, or the Bothnian formation, which lies in discordance of stratification on the foregoing. This consists of detrital matter, showing distinct sedimentary structure, and developing a thickness of four to five thousand metres. Its beds are nearly or quite vertical, and while plainly of fragmental nature they are also distinctly crystalline. They are phyllytes which approach argillytes and sometimes pass into a fine-grained mica schist, and when they contain feldspar they present a gneissic character. But the most remarkable feature of the Bothnian formation is the prevalence of conglomerates. The pebbles vary from microscopic grains to half a metre in diameter. They are well rounded, the greater part consisting of different porphyritic effusives, but there are also pebbles of porphyroids, phyllyte and leptyte. This conglomerate has a crystalline cement, and, along with the phyllytes it is converted into mica schists. The forms of the boulders are most distinctly outlined on weathered surfaces, but when freshly broken they are so intimately blended with the cement that it is impossible to distinguish their limits; except that, frequently, the secondary feldspars are more profusely or more sparingly developed in the boulders than in the rest of the rock surrounding. The beds of conglomerate alternate with a dark green schist, which, according to Sederholm, is a metamorphic volcanic tuff, cotemporary with the conglomerates. The Bothnian formation seems to parallelize well with the Upper Keewatin of Minnesota, both petrographically and structurally.

The latest granitic invasion in Finland, as described by Sederholm[1] in the guide-book of the excursions of the Seventh International Congress of Geologists, is that which cuts the Bothnian formation. The earlier granite, and the earlier schists associated with it, are found in fragments in the

Bothnian formation all along the contact of the basal conglomerate on the pre-Bothnian gneiss; but the post-Bothnian granite, which forms a large area next north of the Bothnian schists, never occurs as pebbles in the schist, but as dikes which are plainly of later date than the schist. It penetrates the schist intimately, causing them to appear like a granetized schist.

These phenomena are identical with those seen in Minnesota, where large areas of the clastics are affected by the metamorphism incident to a granitic boss rising amongst the schists and sending into them numerous apophyses and converting them to schists and gneiss. This granite therefore may be compared with our post-Keewatin granites seen at Kekequabic lake and about Snowbank lake.

The only representative of our greenstone Lower Keewatin (our Kawishiwin) in Finland so far as now appears, is the basic inclusions found in the pre-Bothnian granites.

The Minnesota and Finland Archean seem to be adjustible for comparison in the following manner:

IN MINNESOTA.	IN FINLAND.
Granitic protrusion and metamorphism.	*Post-Bothnian granite.*
Upper Keewatin.	*Bothnian schists.*
Standing vertical, distinctly bedded, clay slates, graywackes, conglomerates, of great thickness, sometimes changed to mica schists and to prophyroids.	Conglomerates, phyllytes, leptytes, frequently rendered crystalline by metamorphism, forming mica schists and porphyroids.
Granitic and felsitic irruption and metamorphism.	*Pre-Bothnian granite* and gneiss.
Lower Keewatin.	
Graywackes, varying to greenwackes by increased amount of chloritic and uralitic ingredients. Conglomerate, jaspilyte; also vast amounts of greenstone which is apparently of igneous origin and structure, this being at the bottom. The fragmentals are extensively converted into mica schists and gneiss.	*The greenstones* seem to be wanting, or are seen only as inclusions in the pre-Bothnian granite.

In Canada, as is well known, the basal gneiss, or fundamental gneiss, was described by Logan many years ago, and was named Laurentian. Along with this was also described an Upper Laurentian which later has been rather discarded

since its principal component, the anorthosytes of the region, has been found to be of igneous origin, and hence not a reliable integral in a stratigraphic scheme. The Lower Laurentian, or Laurentian proper, is divisible into two parts, viz: the fundamental gneiss proper, known also as the Ottawa gneiss, and the Grenville series. In the Grenville series are limestones, quartzytes and other interstratified beds which were undoubtedly derived originally from sedimentary deposition, and this series, according to later observations, lies non-conformably on the Ottawa gneiss. It is not known what chronologic relation the Upper Laurentian, later known as the Norian, bears to the Grenville series, except that it is of later date. It may have been its immediate successor, or there may have been a long interval of time, not there represented in the stratigraphy, which elapsed between their dates of formation. General considerations, however, of stratigraphy and of lithology which the writer has presented elsewhere indicate that there was no important interval of time between them, but that probably the event which closed the Grenville age was the anorthosyte invasion. General considerations also show that it is probable that the Grenville series is represented in the Adirondack mountains, where a similar series of gneisses associated with anorthosyte is widely extended. This series, characterized by marbles and quartzytes, extends into Vermont and southward to New York and into New Jersey. In Vermont and in New Jersey it is found that the limestones are fossiliferous with Taconic trilobites, and that the series is hence of Lower Cambrian age.

It appears probable, therefore, that the Laurentian of Canada, as recently re-defined by some of the Canadian geologists, is divisible between the Archean and the Lower Cambrian, and hence that the divisions which have been given to the Archean in that country cannot be the equivalent of divisions which appear in Minnesota and in Finland. In other words, it is probable that the divisions above detailed for Minnesota and Finland are wholly embraced in the lower division of the Canadian Laurentian, i. e., in the Ottawa gneiss, and that they have not yet been noted in Canada. How much of the Ottawa gneiss is to be attributed to the metamorphosed condition of fragmental strata which in other places in

Canada pass under the name Huronian, the equivalent of the metamorphosed condition of the Keewatin of Minnesota, is unknown, but it is quite likely that, as in Minnesota and in Finland, rocks occupying the position of the so-called Huronian of Canada also become crystalline and in that condition could not be distinguished from the typical Ottawa gneiss.

It is worthy of note also that the fundamental gneiss of Canada is therefore not the bottom of the geological series, but that it is largely a sedimentary formation, and that the debris which went into its constitution was from some still older series, and that this older series, or at least a portion of it, was a greenstone, in part massive and in part stratified, as indicated by the stratigraphic succession in Minnesota.

USE OF THE TERM AUGUSTA IN GEOLOGY.

By Charles R. Keyes, Des Moines, Iowa.

In a recent paper* on "The Batesville Sandstone of Arkansas" there occurs the following statement:

> "Some confusion has been introduced into the nomenclature of the Mississippian formations in the adoption, by the Geological Surveys of Iowa and Missouri of the term Augusta in place of Osage, for this series [Osage Group] of strata. The name Osage was first proposed by Williams in 1891 (Bull. U. S. Geol. Sur., No. 80, p. 409 [169]) to include the Burlington and Keokuk groups of earlier authors. In 1892 Keyes (Bull. Geol. Soc. Am., vol. 3, p. 298) adopted the same name, giving it the same significance, but in 1893 he proposed the name Augusta (Iowa Geol. Sur., vol. 1, p. 59) for the same series of strata. At the time of the proposal of the name Augusta it was recognized by its author as synonymous with Williams' term Osage; the only excuse offered for the adoption of the new name was that at the localities on the Osage River, from which the name Osage was derived, only a portion of the whole series of strata are present, while at Augusta, Ia., a more complete section is exposed. This is, of course, an invalid reason for the introduction of such a synonym into geologic nomenclature. Other series of geologic strata have been named from localities where only a portion of the whole series is exposed. The Chemung group in a well established division in the New York series, yet at the typical locality, Chemung Narrows, only a small portion of the whole formation is exposed. Other instances of the same kind could be

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*Trans. New York Acad. Sci., vol. XVI, p. 280, 1897.

mentioned, but this is enough to show that such a precedent has been established."

Attention is called at this time to the central point in the note for several reasons: (1) There are inadvertently introduced into this short paragraph seven mis-statements of fact, five misrepresentations of published opinions on the subject, and no less than four other deceptive factors, all of which, if allowed to pass unnoticed, will have a tendency to perpetuate "some confusion in the nomenclature of the Mississippian formations"; (2) to avoid, if possible, further expression of erroneous statements which have been already several times repeated; and (3) to present more clearly, than has been perhaps heretofore done, the exact meaning of the term in question as understood in its original definition.

In the first place the proposal of the term Augusta for one of the main subdivisions of the Mississippian series was not with the intention, as implied in the paragraph just quoted, of enlarging the already burdensome synonymy that was known to exist in the nomenclature of the geological formations of the continental interior. In direct opposition it was an attempt to find a name that would not only be appropriate, but that would meet all the requirements of a recognized definition of a geological formation. None existed at the time for the subdivision defined, though the title Osage, as originally proposed, had been evidently intended to occupy a somewhat similar position—not identical as is shown farther on. The latter name possibly might have been extended so as to cover all the formations included by the other term had it been found otherwise suitable. Inasmuch as Osage, after careful investigation, did not prove to be adaptable it was thought best to suggest a term that would obviate entirely all the objections that stood so conspicuously against the other.

Previous to the time of the formal proposal to unite the Burlington and Keokuk limestones under a single title, the strata of the Mississippi basin that were regarded as making up the lower Carboniferous series were commonly grouped under six principal heads, viz: (1) Kinderhook, (2) Burlington, (3) Keokuk, (4) Warsaw, (5) St. Louis, and (6) Chester or Kaskaskia. These were the names which were used almost invariably to designate the formations. Each was made up of

several minor subdivisions which were widely recognized, and some of them had even received special names.

For over a quarter of a century little attempt was made to deviate from the old classification. As the more recent workers in the region came to investigate critically the formations and their fossils, it soon became manifest that an arrangement different from the existing one more nearly expressed the natural sequence of events, and that several of the commonly recognized formations which were regarded as distinct, were really parts of a single one. Among others the Lower Burlington, the Upper Burlington and the Keokuk limestones appeared to be very closely related. As early as 1862 White* had called attention to the near relationships of the crinoids of the three formations. Subsequently Wachsmuth and Springer† revived the discussion. A decade later‡ particular stress was laid on the desirability of uniting the two Burlington limestones and the Keokuk. No name was suggested at this time for the reason that there were strong indications that other and higher beds should be also included. Until these higher deposits could be carefully examined it was thought best not to propose any new titles, and accordingly the naming was left open. Three years afterwards,§ before the beds referred to could be inspected over their full areal extent, the term Osage, which had been proposed in the meanwhile for the Burlington and Keokuk together, was used provisionally in an extended sense.

The term Osage was first proposed by H. S. Williams‖ to embrace the formations previously called the Burlington and Keokuk limestones, the Warsaw being placed in a higher or Ste. Genevieve. The original intention was to use, in this connection, the term Ozark, and this name was actually printed in a paper by professor Williams entitled "A Preliminary Report on the Upper Palæozoic Faunas of Missouri," that was to form pages 103 to 110 of Bulletin 3 of the Missouri Geological Survey, issued in 1890. Owing to certain changes

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*Jour. Boston Soc. Nat. Hist., vol. VII, pp. 224-5, 1862.

†Proc. Acad. Nat. Sci., Philadelphia, 1878, p. 224.

‡Am. Jour. Sci., (3), vol. XXXVIII, pp. 191-192, 1889.

§Classification Lower Carb. Rocks Miss. Valley, Pamphlet, pp. 24, Washington, 1892.

Bull. U. S. Geol. Sur., No. 80, p. 160, 1891; and Ibid. p. 205.

that were to be made, the paper was withdrawn after the page proofs had been read, and it was never publishel, as the material was largely incorporated in another and more extensive memoir on the same subject which was to appear at the same time. The printed, though unpublished Williams' notes are of interest in this connection on account of containing a clearer expression of the real meaning of the term Ozark (Osage) than is found anywhere else. It is as follows:

> "The Ozark group (D. of my table) is a group proposed to include the formations heretofore described as Encrinital limestone, Burlington limestone, Keokuk group, and their equivalents in Missouri, Illinois and Iowa, and part, if not all, of the Siliceous group of Tennessee, all of the faunas of which indicate a close paleontologic relationship. It is possible that some of the formations heretofore referred to the Warsaw group may more properly belong in this group.
>
> The name Ozark group is suggested by the fact of the prominent development of the formations constituting the group on the southern and western margins of the Ozark uplift."

Before the publication of the name Ozark for the Burlington and Keokuk it was learned that the name Ozark was to be used by Prof. Broadhead in another connection and that the paper announcing the fact was already in press. At the suggestion of the latter the term Osage was substituted.

While the matter was pending in Missouri Prof. Williams also made a communication to the Arkansas Geological Survey on the same subject, using the name Osage. Subsequent and more exact correlations made in Arkansas show tnat the formations included* in the "Osage group" were quite different from those included in the same group in Missouri, and embraced also a number of strata of uncertain age, some of which are now known to form a part of the Kaskaskia. Although later investigation showed clearly that a number of formations that do not properly belong there were included in the Osage, there is no definite intimation that Prof. Williams at any time intended to take in any other members than those beds commonly referred to the Burlington and Keokuk. Indeed every reference made by this author to the subject seems to indicate beyond all doubt that no other meaning is to be attached to the term. In every allusion to the suc-

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*Arkansas Geol. Sur., Ann. Rep., 1888, vol. IV, p. xiii, 1891; and ibid Ann. Rep., 1890, vol. I, p. 113, 1891.

cession containing the beds in question the typical Warsaw is carefully excluded and placed in the St. Louis, as was done by Worthen and most others. This is most distinctly shown by the reference, quoted above, to the "Keokuk group" being included in the Osage, for the "Keokuk group" expressly excluded the typical Warsaw beds.

Another important point in the proposal of the term Osage and the selection of the name from a locality in southwest Missouri was that, owing to the unsatisfactory and indefinite character of the then existing literature and notes pertaining to that region, there was thought to be a "mingling of faunas of both Burlington and Keokuk beds." Later investigation, however, has shown that Chouteau and the two limestones already mentioned are as sharply contrasted lithologically, faunally and stratigraphically as along the Mississippi river where these formations are typically developed.

In the prosecution of the geological survey of Missouri the Carboniferous deposits were given special stratigraphical attention. The formations of the Mississippian series (Lower Carboniferous) were taken up in particular and traced from the typical localities on the Mississippi river through the central into the southwestern part of the state. In the original locations in southeastern Iowa, the Lower Burlington, the Upper Burlington, the Keokuk, and the Warsaw (which had been generally placed in the St. Louis) were found to contain essentially the same faunas, showing a continuous and progressive evolution from the base to the top of the sequence. Southwestwardly, around the Ozark uplift the typical section was found as far as the Missouri river, but beyond this point, for a distance of over 100 miles, was more or less largely removed through erosion (previous to the deposition of the Coal Measures). The whole Lower Carboniferous belt rapidly narrowed from a width of 75 miles on the north and on the south to less than a dozen miles, and at some points was reduced to a mere thread, with only a limited vertical exposure in the low bluffs of some stream. In the extreme southwest parts of Missouri and in Indian territory and Arkansas the Burlington and higher formations again assumed their full development and features almost identical with those shown in

the typical localities. With these conditions existing it did not seem advisable to attempt to retain the term Osage. Theoretically the Osage river should cut through the whole Lower Carboniferous; in reality it touched only the lower portion, no higher than upper part of the Lower Burlington. To one who had not visited the locality it was safe to assume that the full sequence was present; accidental circumstances intervened. It was not feasible either to use the term in a sense entirely new from that originally intended, or to modify it to such an extent as to make it meet all the objections that it presented in its original form.

On the whole, after the most careful deliberation, it was decided that much less confusion would ensue, and the ends of geological nomenclature would be better subserved by dropping the name Osage, and using some other term, especially since the subdivision covered by the term Osage and that to be called by the new title were not the same. The objections urged against the extension of the word Osage for one of the main subdivisions of the Mississippian series were as follows:

1. The lines of demarkation for certain of the principal subdivisions of the Mississippian series are not to be drawn at the horizons indicated by the name Osage, if the faunal characters of the sequence are to be taken into consideration, and if the most natural divisional planes are to be sought. Were it not for this one fact the other objections raised might be passed over, and the application of the term extended. The most serious stumbling block in the way of the proper consideration of the Mississippian formations has been the Warsaw, and the general misconception regarding the various beds called by this name but belonging to many different horizons, has done more than any other factor in preventing a clear understanding of the Lower Carboniferous stratigraphy of this region.

2. The unfortunate selection of the section to be considered the typical one. As a matter of fact it is the most non-typical one known.

3. Only a single one of the six distinctive formations belonging to the subdivision is present in the vicinity of the typical section of the Osage. As already stated, the Lower Burlington limestone, and this not fully, appears to be the only

part represented on the Osage river, and the width of the belt occupied by the formation is practically reduced to nil. It is a mere vertical exposure of very limited extent in low river bluffs, with the Chouteau limestones at the base and the Coal Measures at the top.

4. The chief reason for selecting the term Osage—that there is a mingling or mixing of Keokuk and Burlington forms in southwest Missouri—does not appear valid, since the successive faunas are, in reality, as sharply defined and as clearly separated from one another as they are farther north, in southeastern Iowa.

The desirability of a definite term to properly express the stratigraphical and faunal relationships of a part of the Mississippian series being recognized, and no name already in use being available, even by the most liberal modification of meaning, a title was selected from the neighborhood of the typical developments of the several formations that it was proposed to unite. Hence the suggestion of Augusta.

Instead of "at the time of the proposal of the name Augusta was it recognized by its author as synonymous with Williams' term Osage" it was considered as distinctly not synonymous. Furthermore a recent note received from the author of Osage states that the term Augusta will probably have to stand. It may be inferred, therefore, that any "confusion introduced into the nomenclature of the Mississippian formations by the term Augusta in place of Osage" has not been "by the Geological Surveys of Iowa and Missouri."

[European and American Glacial Geology Compared. III.]

DRUMLINS IN GLASGOW.

By Warren Upham, St. Paul, Minn.

The sight of a few drumlins near Appleby, Grasmere, and Keswick, as noted in the second paper of this series, made me eager to see more of these peculiar drift hills, of which, so far as they are developed in England and Scotland, little has been written. In our journey from Keswick, over the Solway lowlands and past the Cheviot hills to Edinburgh, and onward in the moderately hilly agricultural region of eastern

and northern Scotland to Inverness, although drumlins were constantly looked for, none were seen and the outlook on each side from the railways is generally extensive, ranging miles away, over cultivated or pastured tracts, without woods to conceal the glacial drift and the minor topographic features.

Returning southward along loch Ness and the Calendonian canal, with its other lochs, in the Great Glen of Scotland, which divides the mighty mountains of the Highlands by a pass only about 100 feet above the sea, to Fort William, and thence continuing southward by the recently built West Highland railway, by lochs in deep mountain gorges, over broad, high moors bearing many marginal moraines, and through the grand and beautiful scenery of loch Lomond, loch Long, Gare loch, and the Clyde estuary, still I saw no drumlins. But as our train came into the northern suburbs of Glasgow, passing Mary Hill, Possil Park, and Cowlairs stations, many drumlins were observed, closely adjoining our railway on each side and promising, by their admirably typical development, that they were part of a very interesting drumlin district.

During the next three days, July 3rd to the 5th, of last summer, I walked nearly fifty miles in the city of Glasgow and its near environs to map its seventy-five and more drumlins, which have the same irregular distribution and frequently compound grouping as in southern New Hampshire and northeastern Massachusetts, where I had mapped many of these remarkable drift hills, the first so delineated and particularly described in America, twenty years ago.* In more recent years the thorough exploration by Prof. George H. Barton has recorded the detailed distribution and special characters of the fifteen hundred drumlins of Massachusetts, a state which has many tracts of these hills similar to Glasgow, but scarcely any superior. The Glasgow drumlins are closely like those of New England in their outlines, being smoothly oval, and trending east-southeasterly in parallelism with the drift transportation and striæ; in their material, which is the usual till or boulder-clay, rarely containing a nucleus of rock; in their areas, from a quarter to two-thirds of a mile long, with mostly

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*Geology of N. H., Vol. III, 1878, pp. 285-300, with a heliotype plate, a section, and five atlas sheets.

a half to two-thirds as great width; and in their altitude, which is mostly from 50 or 75 to 125 feet above the contiguous lower ground, while their extremes range from 30 or 40 feet up to about 150 feet.

None of the drumlins of Glasgow are extremely elongated and sharp-crested, like some in the Central New York district, and like the ispatinows described and so named by Tyrrell in the north central part of the Dominion of Canada, west of Hudson bay; nor are any of quite circular area, like the mammillary drumlins of some localities in Wisconsin, as described by Chamberlin. From whatever point of view they are seen, the Glasgow hills rise in the graceful rounded forms which suggested to Hitchcock the early name, "lenticular hills," applied to them in the third volume of the New Hampshire Geological Survey.

These hills, hitherto unnoted by geologists or mentioned in the briefest terms in papers treating of other portions of the geology of the region, are, I think, the first drumlins definitely mapped in Great Britain; but in the Iar-Connaught region of Ireland, somewhat more elongated drumlins, occurring in great numbers, were mapped so early as in 1872 by Kinahan and Close. It is to be hoped that the Scottish and English drumlins will soon have equally elaborate mapping, that their general distribution and grouping may be well known, leading probably, with the similar studies made in America, to a good agreement among geologists in their explanations of the mode of accumulation of these prominent smooth hills of glacial drift.

Perhaps the most significant fact concerning drumlins is their gregariousness. Both in America and in the British Isles, they are amassed on some tracts in great profusion, while other and much more extensive drift-bearing regions have none. On the great glaciated areas of continental Europe, only very few and limited districts bear drumlins. Their most notable district was described by Keilhack, with mapping of the many drumlins, two years ago, on the east side of the lower part of the river Oder, in northern Germany.*

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*Jahrbuch, k. preuss. geol. Landesanstalt, 1896, pp. 163-188, with maps. About 2,200 drumlins are mapped by Keilhack in this district; but many of small size are omitted from his map. The whole number of drumlins in this district, which is 60 miles long from north to south and from 20 to 40 miles wide, is estimated at 3,000. They are mostly from 15 to 50 feet high, but some attain hights of 80 to 100 feet.

Some of these drumlins are much elongated, to an extent of two or three miles; and their longer axes trend toward an adjacent looped marginal moraine, betokening their deposition and moulding by the ice-sheet at the same stage, during its general retreat, when the moraine was formed. In Sweden, so far as Baron De Geer has observed during very extensive explorations, drumlins are almost entirely absent. In my journeys through Holland, Germany, Denmark, Norway to Trondhjem, and thence east into Sweden and south in that country to Stockholm and Göteborg, no drumlins were found: and I fully agree with De Geer that probably they are nowhere well developed on the Scandinavian peninsula.

Why and how did the ice-sheets form so abundant drumlins in some limited parts of New England, as notably about Boston and Worcester, also in New York and southeastern Wisconsin, in the Iar-Connaught district, and in the Clyde valley at Glasgow, while other areas apparently not less favorably situated are destitute of such hills? and in what way could the broad, deep sheets of slowly moving land-ice heap up these prominent masses of the unmodified glacial drift? It is entirely easy to account for the retreatal moraine hills of our continental ice-sheets, of which we have the counterparts at the ends of now existing glaciers. Scarcely more difficulty is encountered in ascertaining the mode of formation of kames and eskers, which are knolls and ridges of modified drift gravel and sand deposited by streams walled in part by ice and therefore left by its melting in high pinnacles and ridges. Drumlins, on the other hand, differ from any observed product of the present puny glaciers of the Alps and other mountain districts; but Chamberlin's observations and photographs of the borders of the Greenland ice-sheet give some suggestions of their origin.*

The view which appears to me to afford the fullest explanation of the origin of drumlins, in a brief statement, refers their accumulation to convergent currents of the irregularly indented and channelled border of the ice-sheet during its retreat, when a layer of drift, having become superglacial, as on the Malaspina glacier, was enveloped by a later onflow of

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*Bulletin, Geol. Soc. Amer., Vol. VI, pp. 199-220, with eight plates, Feb. 1895.

ice above it, being then amassed englacially or subglacially in these hills very near to the boundary of the ice, that is, within a few miles or probably in some cases within even less than one mile.* They are thus attributed to unusual conditions of climate interrupting or slackening the recession of the glacial boundary at the close of the Ice age, being exceptional accumulations of the ground moraine, somewhat analogous to the knolly and irregular masses of marginal moraines, but of much rarer development and probably nowhere traceable in such prolonged belts.

For concise presentation of my notes of the Glasgow drumlins, they are herewith arranged in a table; and outlines of these hills, with their altitudes in feet above the sea, are given on the accompanying map, which also shows the railways of the city and their stations, while the streets, on so small a scale, are necessarily omitted. The area mapped is about five miles square, the greater part of which is occupied by the city, the commercial and manufacturing metropolis of Scotland, which has grown during the past hundred years from about 80,000 to about 900,000 people.

Beyond the limits of the map, numerous other drumlins were seen within a few miles, and some of them were ascended and examined. The most conspicuous of these is Gilshoc hill, on the northwest, rising about 275 feet above the sea and 175 feet above its western base, close outside the map border, near Mary Hill railway station and near the crossing of the river Kelvin by the Forth and Clyde canal.

In the following table, the order of the drumlins shown on the map is from north to south, and secondarily from west to east, with numbering for possible reference in any later work. Numbers 1 to 16 are west of the river Kelvin; numbers 17 to 44 are north of the Forth and Clyde canal and of the Monkland canal continuing eastward; numbers 45 to 59 are east of the river Kelvin and south of the canal; and numbers 60 to 87 are south of the river Clyde. In two columns

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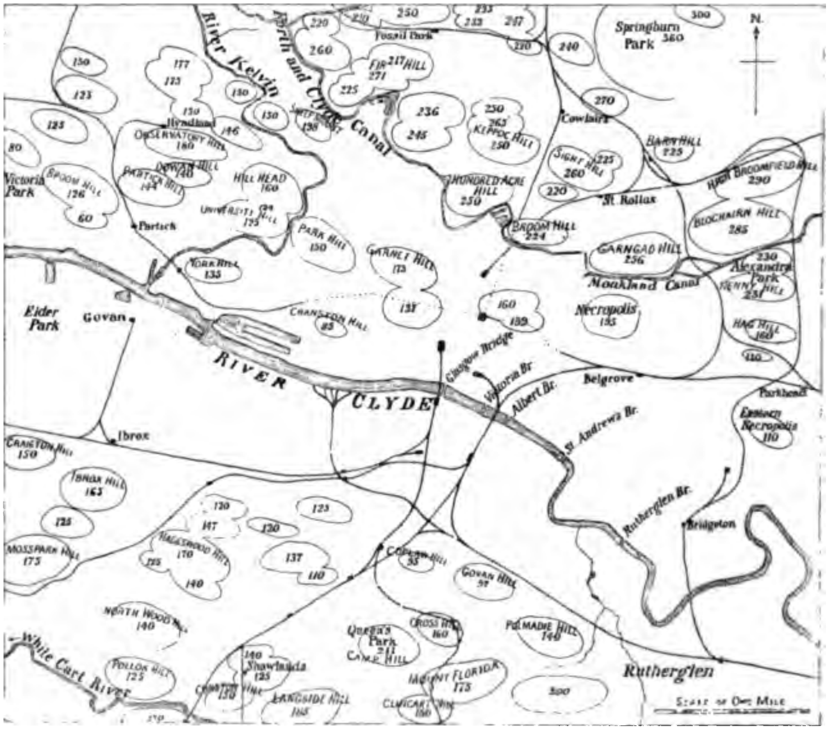
*Boston Society of Natural History, Vol. XXIV, pp. 228-242, April, 1889; Vol. XXVI, pp. 2-17, Nov. 1892, with discussion by Profs. W. M. Davis and George H. Barton (pp. 17-25). Am. Geologist, Vol. X, pp. 239-262, Dec., 1892, including bibliographic notes; Vol. XIV, pp. 69-83, Aug. 1894, with maps and sections.



DRUMLINS IN GLASGOW.

the altitudes of the hill tops are given, first, above the Clyde and the sea, and, second, above the base of the hills. Exact altitudes from the published Ordnance Survey sheet are transcribed for many of the hill summits; but others, with all the hights above the bases, are estimated. The ratios of elongation of these drumlins are stated in the quotient of the length divided by the width. Streets crossing the drumlins in the city are noted, precedence being given to streets running parallel, or nearly so, with the trends of the hills, that is, from west to east or southeasterly, while the second street named crosses the other upon the hill.

NOTES OF THE DRUMLINS OF GLASGOW.

	NAME.	Hight in feet above sea.	Hight above base.	Length / width.	Streets, and other remarks.
	West of the River Kelvin:				
1.	Flemington hill...........	150	75	2	Beside the Great Western Road.
2.	Asylum hill................	123	60	2	Royal Lunatic Asylum.
3.	Woodcroft hill.............	125	60	2	Woodcroft House.
4.	Next S. W.	80	50	2	N. E. of Victoria Park.
5.	Broom or Oswald hill.....	126	100	2	Crow Road; Broom Hill Drive.
6.	Jordan hill.................	60	40	2	Beside Dumbarton Road.
7.	West Balgray hill..........	177	100	2	West Balgray House.
8.	Montgomerie hill..........	175	100	2	Montgomerie Crescent.
9.	Close S.	150	75	1.5	Great Western Road.
10.	Garden hill................	146	75	2	Royal Botanic Garden.
11.	Academy hill..............	150	75	1.4	E. of Kelvinside Academy.
12.	Observatory hill	181	100	2.5	Glasgow Observatory.
13.	Dowan hill.	140	100	2	Crown Terrace.
14.	Partick hill...............	144	120	2	Partick Hill St.
15.	Hill Head..................	160	120	1.5	Great George St.; Hillhead St.
16.	University hill............ formerly Gilmore (Gilmour) hill.	125	100	1.7	Cut down about 50 feet from its original hight.
	North of the canal:				
17.	Tam's hill, most N. W. ...	220	75	1.5	Numerous large drumlins within two miles W. and N.
18.	Close S......................	260	125	1.7	N. of Ruchill station.
19.	Next E......................	210	60	1.8	Cut by railway.
20.	Possil Park hill...........	250	100	2	Park House.
21.	Fir hill N.E...............	217	50	2	Ruchill Hospital.
22.	do., Central...............	271	100	2	Ruchill Park.
23.	do., S. W.	225	75	1.4	do.
24.	Next S. E..................	236	85	1.7	Allander St.
25.	Hamilton hill..............	245	100	1.7	W. of Hamilton Hill House.
26.	Keppoc hill, N.	250	75	2	Allander St.; Ashfield St.
27.	do., Central................	265	90	2	W. of Cowlairs Works.
28.	do., S.......................	250	75	2	Wardlaw St.
29.	Hundred Acre hill.........	250	100	1.6	S. of St. John St.
30.	E. of Possil Park...........	235	50	2.5	Between the Saracen
31.	station, four	232	50	2	Foundry and Ashfield;
32.	summits, N., S.	247	65	1.5	No. 33 cut by railway.
33.	E., and S. E.	220	40	1.5	
34.	Next E.....................	240	60	1.6	Carlyle St.
35.	E. of Cowlairs station.....	270	90	1.6	Hill St.; cut by railway.

Much till is smoothly amassed on the western slopes of the rock highland of Springburn Park (360 feet above sea).

	NAME.	Hight in feet above sea.	Hight above base.	Length / width.	Streets, and other remarks.
36.	N. E. of Springburn Park.	300	75	2	Frequent drumlins seen eastward; few northward.
37.	Peter's hill.................	225	40	1.5	N. of Peter's Hill Road.
38.	Sight hill...................	260	75	1.8	Sighthill Cemetery.
39.	Next S......................	220	40	2	W. of St. Rollox station.
40.	Broom hill..................	224	65	2	Two railway tunnels.
41.	Garngad hill...............	256	90	2	Garngad Hill St.
42.	Barn hill..................	225	50	1.6	Poorhouse.
43.	High Broomfield hill......	290	125	2	Garngad and Milton Road.
44.	Blochairn hill.............	285	125	2	Blochairn Road and House.

East of the River Kelvin and south of the canal:

45.	Kelbourne hill	150	80	1.5	S. of Kelbourne St.
46.	Sheep mount	198	125	1.6	Oxford and Cambridge Drives.
47.	York hill	135	110	2	E. of York Hill station.
48.	Park hill	150	125	1.8	West-End Park and Circle.
49.	Cranston hill	85	50	1.6	Cranston St.; Lancefield St.
50.	Garnet hill	175	100	1.8	Hill St.; Scott St.
51.	Close S.	137	100	1.5	Jane St.; Douglas St.
52.	Next E.	160	100	2	Holmhead St.; Frederick St.
53.	Close S. E.	139	100	2	Richmond St.; Montrose St.
54.	Necropolis hill	195	100	1.4	Cemetery; rock veneered with till.
55.	North hill in Alexandra Park	230	80	1.7	Nos. 55 and 56 in Alexandra Park.
56.	Kenny hill	231	80	2	
57.	Hag hill	174	75	2	Haghill House.
58.	Next S.	110	25	2	W. of Nursery.
59.	Eastern Necropolis hill	110	50	1.6	Cemetery.

South of the River Clyde:

60.	Craigton hill	150	90	1.6	Craigton House.
61.	Ibrox hill	165	100	1.5	Bellahouston House.
62.	Next S. W.	125	60	1.6	S. of Weariesston House.
63.	Mosspark hill	175	110	1.5	S. of Mosspark House.
64.	S. of Bellahouston station.	120	70	2	N. of Nithsdale Road.
65.	Close S.	147	90	2	S. of this road.
66.	Haggswood hill	170	100	2	Haggbowse.
67.	Close S. W.	125	50	1.5	E. of Mossfarm Cottage.
68.	Close S. E.	140	70	2	Haggswood Nursery.
69.	North Wood hill	140	70	1.5	S. part of woods.
70.	Pollok hill	125	50	1.7	E. of Pollok House.
71.	Pollokshaws hill	150	75	2	W. of railway station.
72.	S. W. of Pollokshields station	125	75	2	Bruce Road.
73.	Next S. W.	120	70	2.5	Between Aytoun and Nithsdale Roads.
74.	Next S.	137	85	2	Newark Drive; Leslie Road.
75.	Close S. E.	110	60	2	Titwood Nursery.
76.	Shawlands hill	140	75	1.8	Cut by railway.
77.	Close S.	125	60	1.8	Maxwell St.
78.	Conston hill	150	75	1.8	Cut by railway.
79.	Langside hill	185	100	2	Langside House.
80.	Camp hill	211	140	1.5	Queen's Park.
81.	Cross hill	160	90	1.6	Queen Mary's Ave.; cut by railway.
82.	Mount Florida	175	100	2	Prospect Hill Road.
83.	Clincart hill	160	80	1.8	Cut by railway.
84.	Coplaw hill	95	40	1.8	Nursery.
85.	Govan hill	97	50	1.7	Govan Hill St.
86.	Polmadie hill	140	100	1.8	S. of Polmadie House.
87.	Next S.	200	125	2	New House.

In passing by railway northeast and east, through Bishopbridge and Falkirk, to Edinburgh, drumlins were seen in fair development for about ten miles from Glasgow. Somewhat fluted contour of the till is observable thence to Edinburgh

and to Dunbar, with rarely a typical drumlin; a few drumlins being noted near Linlithgow, and again a few miles west of Dunbar. But none were seen farther southeast and south, on the route to Berwick, York, Cambridge, and Harwich.

The Carboniferous bed-rocks of Glasgow lie generally at only a slight depth beneath the bases of the drumlins, forming the general ascent of the country on each side of the Clyde.

A confluent ice-sheet, flowing down mainly from the Grampian Highlands on the north and northwest, but partly from the Southern Uplands, moved eastward over the central Clyde and Forth lowlands and pushed against the Scandinavian ice-sheet, with which it was confluent on the present area of the North Sea. During the recession and departure of these icefields, a time came when the eastern front of the Scottish ice withdrew from the region of Edinburgh westerly past Glasgow; and at that time I think the drumlins of the Clyde district, so abundantly developed in Glasgow, to have been amassed.

Later, when the ice-sheet had retreated so far as to admit the sea to this valley, its fossiliferous beds and shore lines, about 50 and 25 feet above the present sea level, analogues of those of the Champlain epoch in America, extended along the Clyde valley. Men at that early date lived and fished here, and lost their dug-out canoes, of which about twenty, varying from 9 to 27 feet in length, have been found in these marine beds in and near Glasgow. These beds overlie the bases of the lower drumlins near the Clyde. Finally, at the end of the Ice age, the last remnants of the Scottish ice-sheet, which lingered as mountain glaciers, melted away; and the land, relieved from its glacial burden, rose to its present hight. Subsequent time has been short, in a geological sense, for the slopes of the drumlins show scarcely any subaërial erosion; their forms remain as they were moulded by the great overriding sheet of land ice.

REVIEW OF RECENT GEOLOGICAL LITERATURE.

Le Gypse de Paris et les minéraux qui l'accompagnent. A. LACROIX. (Nouvelles Archives des Museum d' Histoire Naturelle, Paris, tome X, 1897.)

It is probably true, as remarked by the author, that there are few sedimentary regions as rich in minerals as the basin of Paris. It is equally true that there are few that have been so thoroughly searched and so long studied. Modern mineralogy may be said to have had its beginning in the Paris basin, and from the same center have gone out successively the great works of Romé de Lisle, Haüy, Brongniart. Becquerel and Decloiseaux. The present work is no mean successor of the earlier parts of this series. The author denominates this his "premier mémoire" on this subject, and promises to follow up the subject, but it is difficult to conceive what further there is to be said.

The gypsum of the Paris basin is found to lie in strata extending from the lower Oligocene to the Senonian of the upper Cretaceous, the last, however, being considered to have received it by secondary deposition. The crystals of gypsum, which are often magnificent, reaching the dimension of six to eight inches, are often twinned and repeated in a multiplicity of ways. These forms are mineralogically described and often illustrated by photography on a series of elegant plates.

The accompanying minerals, often formed by the transformation of gypsum, largely by the action of pyrite and atmospheric air and water, are the following: pyrite, common salt, celestite, menilite, calcite, opal, magnesite, quartz, lutecite, chalcedony, fluorite, apetalite, marcasite, blende, websterite, melanterite, phosphorite, vivianite, siderite, succinite.

Gypsum occurs not only in crystals, but as strata that have a thickness sometimes reaching 90 feet. From these strata it has been quarried for many years, furnishing the celebrated "plaster of Paris."

One of the most interesting of the above minerals is lutecite, a form of quartz, lately discovered and described by Michel-Levy and Munier-Chalmas (Bul. Soc. Min. France, XV, 159. 1892). It is sometimes fibrous and sometimes in macroscopic crystals; when fibrous it differs from both chalcedony and quartzine in the relation the fibers bear, in their greatest dimension, to the axes of elasticity. In chalcedony they are elongated parallel to the index of elasticity n_p and in quartzine parallel to n_g. In lutecite they are elongated in a direction of the plane n_g, n_m, making with n_g an angle which is not yet established definitely but which is about 32 degrees (Wallerant). When lutecite appears in crystals they are short, hexagonal, doubly terminated pyramids, always united in series by their pyramidal faces or twinned by their bases.

N. H. W.

MONTHLY AUTHORS' CATALOGUE OF AMERICAN GEOLOGICAL LITERATURE, ARRANGED ALPHABETICALLY.*

Adams, F. D.

Nodular granite from Pine lake, Ontario. (Geol. Soc. Amer., Bull., vol. 9, pp. 163-172, pl. 11, Feb. 10, 1898.)

Adams, G. I.

A geological map of Logan and Gove counties [Kansas]. (Kansas Univ. Quarterly, vol. 7, ser. A, pp. 19-20, Jan. 1898.)

Ami, H. M.

Notes on the geology of Chelsea, Que., and some of its bearings on the geology of Ottawa. (4 pp.; reprinted with emendations from Ottawa Naturalist, vol. 9, pp. 125-127, Sept. 1897.)

Ami, H. M.

Synopsis of the geology of Montreal. (5 pp., author's edition, Dec. 1897. Ex. British Medical Ass. guide and souvenir, pp. 45-49, Montreal, 1897.)

Becker, G. F.

The Witwatersrand banket, with notes on other gold-bearing pudding stones. (U. S. Geol. Survey, 18th Ann. Rept., pt. 5, pp. 1-36, pl. 1, 1897.)

Becker, G. F.

Reconnaissance of the gold fields of southern Alaska, with some notes on general geology. (U. S. Geol. Survey, 18th Ann. Rept., pt. 3, pp. 1-86, pls. 1-31, 1898.)

Becker, G. F.

The auriferous conglomerate of the Transvaal. (Am. Jour. Sci., ser. 4, vol. 5, pp. 193-208, Mch. 1898.)

Beede, J. W.

New corals from the Kansas Carboniferous. (Kansas Univ. Quarterly, vol. 7, ser. A, pp. 17-18, Jan. 1898.)

Beede, J. W.

The stratigraphy of Shawnee county [Kansas]. (Kans. Acad. Sci., Trans., vol. 15, pp. 27-34, 1898.)

Beede, J. W.

The McPherson Equus beds. (Kans. Acad. Sci., Trans., vol. 15, pp. 104-110, pls. 2-4, 1898.)

Beede. J. W.

Notes on Kansas physiography. (Kans. Acad. Sci., Trans., vol. 15, pp. 114-120, pls. 7-9, 1898.)

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*This list includes titles of articles received up to the 20th of the preceding month, including general geology, physiography, paleontology, petrology and mineralogy.

Berkey, C. P.

Geology of the St. Croix dalles. II. (Am. Geol., vol. 21, pp. 139-155, pls. 12-13, Mch. 1898.)

Blake, W. P.

Oscillations of level of the Pacific coast of the United States. (Am. Geol., vol. 21, pp. 164-165, Mch. 1898.)

Brigham, A. P.

Topography and glacial deposits of Mohawk valley. (Geol. Soc. Amer., Bull., vol. 9, pp. 183-210, pl. 15, Feb. 19, 1898.)

Brown, R. G.

A mineralized dyke. (School of Mines Quarterly, vol. 19, pp. 90-93, Nov. 1897.)

Case, E. C.

The significance of certain changes in the temporal region in the primitive Reptilia. (Am. Nat., vol. 32, pp. 69-74, Feb. 1898.)

Colman, A. P.

Clastic rocks of western Ontario. (Geol. Soc. Amer., Bull., vol. 9. pp. 223-238, Feb. 24, 1898.)

Cross, Whitman.

The geological versus the petrographical classification of igneous rocks. (Jour. Geol., vol. 6, pp. 79-91, Jan.-Feb. 1898.)

Cushing, H. P.

Syenite-porphyry dikes in the northern Adirondacks. (Geol. Soc. Amer., Bull., vol. 9, pp. 239-256, pl. 17, Feb. 26, 1898.)

Dall, W. H.

Notes on the paleontological publications of Professor William Wagner. Wagner Free Inst. Sci., Trans., vol. 5, pp. 7-11, pls. 1-3, Jan. 1898.)

Darton, N. H.

Geothermal data from deep artesian wells in the Dakotas. (Am. Jour. Sci., ser. 4, vol. 5, pp. 161-168, Mch. 1898.)

Davies, H. E.

Kansas mineral waters. (Kans. Acad. Sci., Trans., vol. 15, pp. 82-88, 1898.)

Derby, O. A.

On the accessory elements of itacolumite, and the secondary enlargement of tourmaline. (Am. Jour. Sci., ser. 4, vol. 5. pp. 187-192, Mch. 1898.)

Drake, N. F.

A geological reconnaissance of the coal fields of the Indian Territory. (Am. Phil. Soc., Proc., vol. 36, pp. 326-419, pls. 1-9. Dec. 1897.)

Earle, Charles.

Remarks on the fossil tapiroids of France. (Am. Nat., vol. 32, pp. 115-116, Feb. 1898.)

Earle, Charles.

Note on the structure of the skull in Dichodon (Am. Nat., vol. 32. p. 117, Feb. 1898.)

Elftman, A. H.

The geology of the Keweenawan area in northeastern Minnesota. II. (Am. Geol., vol. 21, pp. 175-188, Mch. 1898.)

Ells, R. W.

Sands and clays of the Ottawa basin. (Geol. Soc. Amer., Bull., vol. 9, pp. 211-222, pl. 16, Feb. 22, 1898.)

Fairbanks, H. W.

The great Sierra Nevada fault scarp. (Appletons' Pop. Sci. Monthly, vol. 52, pp. 609-621, Mch. 1898.)

Gould, C. N.

On a series of transition beds from the Comanche to the Dakota Cretaceous in southwest Kansas. (Am. Jour. Sci., ser. 4, vol. 5, pp. 169-175, Mch. 1898.)

Greene, G. K.

Contribution to Indiana palæontology. Pt. I. (7 pp., 3 pls.; Ewing and Zeller, New Albany, Ind., Feb. 28, 1898.)

Grimsley, G. P.

Gypsum in Kansas. (Kans. Acad. Sci., Trans., vol. 15, pp. 122-127, 1898.)

Grimsley, G. P.

The study of natural palimpsests. (Kans. Acad. Sci., Trans., vol. 15, pp. 127-130, 1898.)

Harnly, H. J.

Cone-in-cone. An impure calcite. (Kans. Acad. Sci., Trans., vol. 15, p. 22, 1898.)

[Hay, Robert.]

Robert Hay. (Kans. Acad. Sci., Trans., vol. 15, pp. 131-133, 1898.)

Hollick, Arthur.

A new fossil grass from Staten island. (Torrey Bot. Club, Bull., vol. 24, pp. 122-124, pl. 298, Mch. 1897.)

Hollick, Arthur.

A new fossil monocotyledon from the yellow gravel at Bridgeton, N. J. (Torrey Bot. Club, Bull., vol. 24, pp. 329-331, pls. 311-313, July 1897.)

Hollick, Arthur.

Affinities of Caulinites Ad. Brong. (Torrey Bot. Club, Bull., vol. 24, pp. 582-583, pl. 320, Dec. 1897.)

Iddings, J. P.

On rock classification. (Jour. Geol., vol. 6, pp. 92-111, pls. 1-3, Jan.-Feb. 1898.)

Ingall, E. D.

Summary of the mineral production of Canada for 1897. (Geol. Survey of Canada, 7 pp., 1898.)

Jones, A. W.

The Mentor beds. (Kans. Acad. Sci., Trans., vol. 15, pp. 111-112, 1898.)

Keyes, C. R.

Structure of the coal deposits of the Trans-Mississippian field. (Eng. and Mining Jour., vol. 65, pp. 253-254, Feb. 26, 1898; pp. 280-281, Mch. 5, 1898.)

Kimball, J. P.

Residual concentration by weathering as a mode of genesis of iron ores. (Am. Geol., vol. 21, pp. 155-163, Mch. 1898.)

Knerr, E. B.

Barite nodules in wood. (Kans. Acad. Sci., Trans., vol. 15. pp. 80-81, 1898.)

Knerr, E. B.

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CORRESPONDENCE.

ARCHEAN CHARACTER OF THE NUCLEI OF THE ANTILLES. In a paper read by me before the British Association for the Advancement of Science at the 15th or Bath meeting in 1888, I explained the petrographic reasons which had led me to conclude after a careful study of a large number of specimens that the rocks forming the nucleus of the island of Cuba were Archean. I also gave reasons why I considered it a not unreasonable inference that Hayti, Jamaica, Porto Rico, and the Windward islands, as well as Yucatan and Florida were likewise provided with Archean nuclei; and that this implied a branch or fork of the Appalachian chain and the enclosure of the Caribbean sea by an Archean wall now largely broken down.

In a paper recently issued by Dr. W. Bergt, on the geology of San Domingo (Zur Geologie von San Domingo, Abhandlungen der Naturwissenschaftlichen Gesellschaft "Isis" in Dresden, 1897, Heft, II) the author fully confirms the suspicion with regard to San Domingo and agrees with my earlier statement of the probabilities of this structure.

These views received the attention of Bonney, Renard and all the petrographers who attended the 4th International Geological Congress, and the 58th Session of the B. A. A. S. in 1888 and I believe the petro-

graphic and structural arguments on which these were based obtained the endorsement of all of them. This later confirmation by special study of a part of the field then not explored, is interesting in itself and in relation to the geological history of the Continent.

Dr. Bergt criticizes unfavorably Gabb's geology of San Domingo.

PERSIFOR FRAZER.

THE INTERGLACIAL DEPOSITS OF NORTHEASTERN IOWA. [Abstract.][*] Interglacial deposits occur at two horizons in the glacial series of northeastern Iowa. The first is the peat and forest bed which, so far as this region is concerned, was first brought to the attention of science by the writings of McGee. The second is the Buchanan gravels of Calvin.

Owen[†] was the first geologist to refer to the drift of northeastern Iowa. He was much impressed by the great bowlders strewn over the surface, and expressed the belief that they had probably been transported to their present position by floating ice. White discussed the drift more fully, and recognized its glacial origin, but the time had not yet come for recognizing the complex nature of the Pleistocene deposits and hence the numerous problems with which more recent investigators have been chiefly concerned were not considered.

It remained for McGee to introduce methods of investigation that finally furnished the key to the interpretation of the complex Pleistocene system. He pointed out in numerous contributions to geological literature that the drift was certainly not single, but that it embraced at least two distinct sheets of till.[§] He insisted that the interval between the two glacial invasions was one of enormous length. He regarded the forest bed as lying between his lower and upper till. He furnished criteria for discriminating the two till sheets by their color and contents. He it was who led the way to a satisfactory classification of the Pleistocene bed of this part of the Mississippi valley.

Recent investigations show that McGee's lower till embraces two distinct drift sheets, and that it is between these two that the forest bed invariably lies. Three drift sheets, therefore, are recognized in northeastern Iowa, and in recent literature referring to Pleistocene geology they are known respectively as Sub-Aftonian, Kansan and Iowan. No forest material has been observed between the Kansan and Iowan, but in this situation there occur extensive beds of stratified sand and gravel.

The forest bed between the first and second drift sheets is frequently accompanied by beds of peat from an inch or less to three or four feet in thickness. The peat beds often cover areas of considerable extent

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[*] Read before the Iowa Academy of Sciences, Dec., 1897.

[†] Report of a Geological Reconnoissance, etc., p. 69, 1848.
Report of a Geol. Sur. of Wis., Iowa and Minn., p. 144, 1852.

[‡] Report on Geol. Sur. of Iowa, pp. 82-102, 1870.

[§] McGee's observations on the drift of this region is well summed up in "The Pleistocene History of Northeastern Iowa," U. S. Geol. Sur., Eleventh An. Rpt., pp. 189-577, 1893.

Where peat is absent at this horizon there is often evidence of an ancient soil, humus stained and weather stained as is the case with modern soils. This soil, peat and forest horizon is correlated with the Aftonian interglacial deposits of southwestern Iowa. It has been encountered in hundreds of wells and has been revealed in not a few instances in railway cuttings. Its development in the great railway cut at Oelwein, Iowa, is discussed in the Proceedings of the Iowa Academy of Sciences,* and its relations to the Sub-Aftonian and Kansan till sheets are well set forth in the extensive series of well sections published by McGee.†

Buchanan gravels were first recognized as a distinct interglacial deposit at the gravel pit of the Illinois Central railway in section 32 of Byron township, Buchanan county, Iowa. A description of this type locality was read before the Iowa Academy of Sciences two years ago and was published in the American Geologist.‡ The beds to which the name was applied consist of stratified sand and gravel. The bedding is in places oblique, showing action of strong currents. Scattered through the deposit are bowlders ranging up to twelve or fifteen inches in diameter, and many of the bowlders still retain perfectly the facets and scratches due to glacial planing. They may have been transported by floating ice. At all events they have not been rolled or abraded to any appreciable extent.

The materials composing the Buchanan gravels have been derived chiefly from northern sources. Furthermore they possess the characteristics of pebbles and bowlders found in the Kansan drift. Certain granites and other rock species are completely decayed, and crumble to fine particles on the application of slight force. Finally the gravels are exceedingly ferruginous and weather stained, particularly near the top of the deposit, the weathered portion taking on a characteristic rusty, reddish brown color.

At the typical locality the Buchanan gravels rest on blue till of Kansan age and are overlain by a bed of fresh Iowan till from two to eight feet in thickness. The Iowan till contains a great number of large sized, light colored granite bowlders, some of which are perched on the brink of the pit, while some have been undermined and have fallen to the bottom. The gravels here clearly lie between two sheets of till. The weathering, oxidation and decay the materials have suffered afford in some degree a measure of the length of the interglacial interval. Two years ago it was the current belief that the Pleistocene deposits of Iowa, except in the area occupied by the Wisconsin lobe, contained a record of two ice invasions and of two only. Accordingly the Aftonian gravels and soil beds which had previously been observed in Union county were assumed to lie between McGee's lower and upper till, and since the Buchanan gravels plainly occupied what seemed to be a similar position, they were first referred to the Aftonian stage. Our knowledge of Pleis-

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*Vol. IV, pp. 54-68 1897.

†Pleistocene History of Northeastern Iowa, pp. 515-540.

‡Vol. XVII, p. 76, Feb. 1896.

tocene deposits has moved with tremendous strides during the past two years. A few points only can be noted. First, Bain showed that the till overlying the Aftonian beds was Kansan; the lower till of McGee, and not the Iowan as had been assumed. This observation necessitated adjustment of views previously held. It added a new drift sheet to the known glacial series of Iowa. It demonstrated that the Aftonian and Buchanan interglacial beds belonged to different horizons. Before that adjustment Chamberlin* had published his classification of American glacial deposits which recognized only the Kansan, Iowan and Wisconsin glacial stages, with two interglacial stages, the Aftonian being referred to the interval between the Kansan and the Iowan. Bain's demonstration of the true position of the Aftonian left the Buchanan gravels as the only recognized deposit, so far published, representing this interval, and the term Buchanan offered itself as a convenient designation for the second interglacial period. In the meantime Leverett† was pushing investigations on a sheet of till younger than the Kansan, but much older than the Iowan, and furnishing proof that the enormously long interval between the Kansan and Iowan ice invasions was not a unit, but comprised three distinct stages of the glacial series. One of these stages, the Illinoian, was glacial, the other two interglacial. When therefore in 1896 Chamberlin‡ revised his classification of glacial deposits, there were five drift sheets to be recognized in place of three. The Aftonian beds were assigned to their true place beneath the Kansan, and the term Buchanan was used for the second interglacial stage.

The Buchanan gravels are connected genetically with events immediately following, or intimately attending the withdrawal of the Kansan ice. The materials were evidently derived directly from the Kansan drift. So far as their deposition is concerned they belong to the very beginning of the interglacial stage following the Kansan. They are much more widely distributed than was at first supposed. They are exposed, in cases with a thickness of thirty feet, at scores of points in each of a number of counties examined, and sometimes hundreds of acres are embraced in a single continuous area. Within the region invaded by Iowan ice they are usually overlain by Iowan till with characteristic Iowan bowlders strewn over the surface. In the northeast corner of Delaware county, and at other points within the Kansan area but outside the margin of the Iowan drift, they are overlain by loess.

The use of the term Buchanan as a name for an interglacial stage is open to criticism. It came into use tentatively before the recognition of the Illinoian drift, as a stage distinct from either Kansan or Iowan, had been published; when the whole period of time between the retreat of the Kansan, and the invasion of the Iowan ice was supposed to be a single, uninterrupted interglacial interval. It was first used in the precise sense in which the term Aftonian was originally used, and as a

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*Jour. of Geol. Vol. III, p. 270, April-May, 1875.
The Great Ice Age, James Geikie, 3d ed., pp. 724-774, 1895.

†Leverett had recognized the Illinoian drift as the representative of a distinct glacial stage as early as 1894, but the fact was not published until 1896.

‡Jour. of Geol., vol. IV, p. 874, Oct.-Nov., 1896.

substitute for that term when it was shown that the Aftonian soils and gravels preceded the Kansan stage. Since the recognition of the Illinoian glacial stage the term has been used for the interval following the Kansan in publications by Chamberlin, Calvin and Scott. No great objection to its continued use can be urged. In fact it is much to be desired that names once introduced should remain undisturbed; but it may after all be a decided gain to Pleistocene geology to select a name for the interval between the Kansan and the Illinoian from some locality where true interglacial deposits are clearly intercalated between Kansan and Illinoian sheets of drift. SAMUEL CALVIN.

THE WEATHERED ZONE (YARMOUTH) BETWEEN THE ILLINOIAN AND KANSAN TILL SHEETS. [Abstract.]* The extent of overlap of the Illinois glacial lobe upon the Kansan sheet of drift deposited by a neighboring lobe on the west is briefly considered. The question of the occurrence of a sheet of drift of Kansan age in the series deposited by the Illinois lobe is left open.

The name Yarmouth, taken from a village standing on the marginal ridge of the Illinoian till sheet in southeastern Iowa, represents the locality where the break between the Illinoian and Kansan till sheets was first recognized by the writer (November, 1888).

The sections showing this break are presented, there being in one section a peat bed 15 feet in depth containing much woody material and also bones of the rabbit and skunk. The latter were brought to notice by Mr. W J McGee in the Eleventh Annual Report of the U. S. Geological Survey.

Natural exposures and well sections along the belt of overlap are presented which show that the development of a soil horizon and the leaching of the Kansan till surface is about as marked as in the Sangamon weathered zone. These exposures extend from Davenport, Iowa, southward to the vicinity of Quincy, Illinois, a distance of fully 100 miles, and are found at frequent intervals throughout the portion of Iowa covered by the Illinois glacial lobe. Fortunately there was sufficient overlap of the Illinois lobe upon the Kansan till surface to make clear the interpretation that the Illinoian is a markedly younger sheet than the Kansan. This difference in age was suspected to occur from a comparison of the maturity of valleys in the two districts; but the testimony of the weathered zone preserved beneath the Illinoian till sheet was necessary to confirm it. FRANK LEVERETT.

THE WEATHERED ZONE (SANGAMON) BETWEEN THE IOWAN LOESS AND ILLINOIAN TILL SHEET. [Abstract.]† After outlining the extent of the Illinoian till sheet, the question of the application of the term Buchanan to the interval between the Kansan and Iowan is discussed as follows:

"Manifestly the deposition of the Buchanan gravels covered but a

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*Read before the Iowa Academy of Sciences, Dec. 1897.

†Read before the Iowa Academy of Sciences, Dec. 1897.

small part of the time between the Kansan retreat and the Iowan advance. Unless therefore the subsequent weathering be included under this name, the Buchanan does not fill an interglacial stage. Were there no Illinioian glacial stage to break the continuity of interglacial conditions from the Kansan to the Iowan stage of glaciation it would seem unnecessary to introduce other names. But in view of this glacial interruption there seems need for names which will stand for the weathered zones above and below the Illinoian till sheet. It is for this reason that the name Sangamon is here proposed for a weathered zone between the Iowan loess and the Illinoian till sheet. The name Yarmouth is introduced in an accompanying paper for the weathered zone between the Illinoian and Kansan till sheets. The name Buchanan may still be retained with the significance given it by Prof. Calvin; and if weathering be included may perhaps be used to cover the time involved in the two interglacial stages and intervening glacial stage which occur between the Kansan retreat and the Iowan advance."

The name Sangamon is taken from the county and drainage basin of that name in central Illinois where exposures showing the break between the Iowan loess and Illinoian till were first discussed in print.* At the type locality the break is filled to a large degree with the accumulation of a bed of peaty muck. This is a feature which characterizes a large part of the Sangamon drainage basin and is one that is perhaps more likely than any other interglacial product to draw attention. It is not, however, the most common and widespread phase. A much more common phase is a reddish brown leached surface of the till sheet. This appears to have been developed in all places where there was good drainage. The black muck indicates poor drainage conditions, and where it is present the reddened zone is weakly developed. Leaching of the surface of the calcareous till is found to have reached an average depth of about six feet prior to the deposition of the loess. The loess deposition is referred chiefly to the Iowan stage of glaciation: the change in the Illinoian surface therefore took place between these two glacial stages. Several noteworthy exposures are cited, in one of which peat reaches a depth of 13 feet, and in several of which a soil and leaching fully equal to that commonly displayed by the Wisconsin or the Iowan may be seen. A kodak view of one exposure taken at a distance of about one-fourth mile shows the Sangamon soil clearly.

Valley excavation during the Sangamon interglacial stage is touched upon briefly. It is shown that conditions were favorable only for the production of shallow valleys, but that these valleys reached in some cases a breadth much greater than the modern valleys of the same streams. FRANK LEVERETT.

THE AFTONIAN AND PRE-KANSAN DEPOSITS IN SOUTHWESTERN IOWA. [Abstract.]† The Aftonian deposits of southwestern Iowa have peculiar interest in that within the area is the type locality for the Aftonian. So far neither the drift of the region nor the Aftonian as a

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*A. H. Worthen, Geology of Illinois, vol. V, 1873, pp. 308-309.

†Read before the Iowa Academy of Sciences, Dec. 1897.

unit has received a general discussion. It should be remembered that the exposures of the Aftonian and the sub-Aftonian are scattered; that their importance was unsuspected until quite recently; that in the nature of things the phenomena may be expected to be somewhat illusive and that but little of the area has received detailed study. In view of these facts the present must be taken as a preliminary statement only and subject to considerable future revision.

The Afton-Thayer exposures were visited by McGee and Chamberlin in company, and the evidence of an interglacial interval here, in connection with the facts derived from a study of other portions of the Mississippi valley, was considered sufficient to warrant the reference of the beds to two distinct periods of glaciation. With a wise conservatism the two periods were assumed to be the same as had been demonstrated in northeastern Iowa, and accordingly in the nomenclature eventually proposed by Chamberlin* the upper drift at Afton was considered to be the Iowan, and the lower the Kansan. The Aftonian beds proper were considered to represent the interval between the Kansan and the Iowan. It is important to note that in the original paper by Chamberlin the term Aftonian was not applied to the gravels which form so conspicuous a feature of the Afton-Thayer sections. These were considered to represent rather kame-like accumulations upon the surface of the older drift sheet. This distinction has not been always clearly observed.

The Afton-Thayer outcrops are for many reasons the most important of those bearing on the question of an interglacial interval in southwestern Iowa and will be described in some detail. Preliminary to this it is desired to examine briefly what sort of evidence may properly be required to establish the presence of two drift sheets. In southern Iowa the most important criteria have been found to be forest beds and buried soils, leached horizons, ferruginated zones ("ferretto horizons"), water-laid beds, topographic changes, and the physical character of the till. The cumulative value of this sort of evidence is believed to be important.

The Afton-Thayer Exposures.

The Aftonian beds are not positively known to occur in or immediately adjacent to the city of Afton; the latter is, however, the best known place near the original exposures. The beds are seen well exposed at three abandoned gravel pits located three to six miles east of Afton proper. These are (1) between Afton Junction and Talmage; (2) about one mile southeast of the Junction on the south side of Grand river; (3) about three-quarters of a mile west of Thayer on the south side of the C., B. and Q. railway. For convenience these will be called the Afton Junction, Grand river and Thayer pits respectively. The Afton Junction pits show the overlying loess, the Kansan drifts and the gravels, with certain buried silts or loess below the latter. The Grand river exposure shows the upper and lower drifts with the gravels be-

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*Great Ice Age (Geikie), pp. 773-774, 1893; Jour. Geol., vol. III, 270-277, 1895.

tween. The Thayer exposure shows the gravels and the overlying drift with certain sands and fine clays between.

Afton Junction. The pits at this place are about 1,500 feet north of the railway station on the west side of the Chicago Great Western. They have been opened along the sides of a small stream running east and emptying into Grand river. The north side of the pit is bilobate, the minor lobe being to the east and not directly in line with the main face of the pit. The two lobes in fact form an arc of a rude circle rather than a straight face. Between the two lobes is a small stream which has cut down to, but not through, the gravels. The main face is about 1,000 feet long and has a maximum hight of probably seventy feet. The minor or east lobe is about 400 feet long and 60 feet high. The bottom of the pit, said to rest on "quick sand," is cut down to about the level of Grand river bottom (1,030 A. T.). The stream is here of the post-Kansan age. The section exposed at the main face is as follows:

	Feet.
Loess of the usual uplift or older type characteristic of the region	10
Yellow boulder clay with upper portion much oxidized leached and highly colored, lower portion running into a blue with weathered joint cracks. Containing much weathered material and planed and striated bowlders. Characteristic Kansan	30
Gravel, corase, cross-bedded, iron stained, cemented in part into hard conglomerate; made up to considerable extent of very badly weathered material. Manifestly an old gravel	40

Down to the gravels this is the normal section for the region and could be duplicated at hundreds of points. The ferretto zone is well developed and its coloring is dark enough to show excellently in a photograph. The drift and loess are identical in every particular with that found throughout southern Iowa and there can be no doubt whatever that the drift is Kansan.

The drift shown in the east lobe is of the same character as that overlying the gravels in the main face, and the identity of the two has not been questioned so far as is known to the writer by any who have visited the place. Among the latter may be mentioned Profs. T. C. Chamberlin, Albrecht Penck, Samuel Calvin and S. W. Beyer. Prof. G. F. Wright and others have seen the exposure, but their opinions on this point are not known to the writer. The drift in the east lobe lies at a considerably lower level than in the main face, extending in fact down to the bottom of the pit. As the railway near the station just cuts into the top of the gravel a few feet, this was, when first seen, interpreted to mean that the gravels formed a kame-like ridge with a northwest-southeast trend and that the drift had been laid over this ridge running down over its side. It was thought likely that there had been some erosion whereby an eastern extension of the gravels had been cut away before the drift of the east lobe was laid down, and that, accordingly, the position of the drift indicated, or at least accorded with,

a certain time interval between the gravel and the overlying drift. Recent studies fail to sustain this view. The Great Western railway company undertook to open up the gravels at the point near the station where they showed above the track. As the steam shovel travelled to the north it was found that the gravel contained more and more clay until ordinary bowlder clay was being handled and the work was stopped. An examination of the east lobe of the old pit shows that the same transition may be traced. In this drift faint lines of stratification may be noticed running through the bowlder clay. So faint are these in the portion some distance from the gravels that they were at first entirely overlooked. Reëxamination showed, however, that the bowlder clay passes into the gravel and vice versa. This relationship has been somewhat obscured by the circumstances of the stream pouring down at the contact; but, when a careful examination is made, the facts are seen to be unmistakable. There is no evidence of erosion, nor are there dynamic phenomena at the contact, such as might have been expected had the gravels been present and a later drift sheet pushed against them. Indeed there is no contact, but rather a transition; that is, the gravels are contemporaneous with the drift and of Kansan age. As this is a point of some moment it may be mentioned that the Reynolds ford gravels in Decatur county, doubtless the extension of those near Afton Junction, show the same lateral transition into drift of presumable Kansan age.

At the extreme east end of the east lobe there is an exposure showing the beds below the drift. This exposure is in a borrow pit made in getting material for the railway fill. The overlying bed here is the yellow clay of the Kansan. It is here so far from the gravels that it shows no signs of stratification nor indeed anything to indicate that it is anything more than the ordinary yellow clay of the Kansan. It can, however, be traced step by step through the slightly stratified drift and from that through the more distinctly stratified beds and so into the gravel. Beneath the yellow bowlder clay there occurs a pebbleless clay resembling the loess. Indeed one might imagine it to be the ordinary drift-loess section of the region reversed and minus the ferretto zone. In fact that is exactly what it is; a loess buried beneath yellow bowlder clay. In all important respects it so closely resembles the ordinary upland loess that the two could probably be discriminated only with difficulty. As the loess shows under the stratified beds at one point in the pit several hundred feet from this exposure, it is clearly not to be explained as a hillside creep. Indeed it is probable that the "quick sand" found beneath the gravel is this loess.

Grand River Section. The exposure on the river proper is about one mile away and one exposure is in view from the other. Between ordinary erosion has cut away the connecting beds; but looking across the amphitheatre the connection is obvious. This section is the only one in the region showing the lower till and is accordingly of exceptional interest. The full exposure shows the loess Kansan drift, and gravels as seen elsewhere. Beneath them are the following beds:

	Feet.
Boulder clay (sub-Aftonian), a blue black clay non weathered at top and coming into sharp contact with the ferruginated gravels, containing mainly small pebbles, predominantly of vein quartz but with a fair proportion of granite. Many if not most of the pebbles fresh and hard	40
Red and blue shales of Missourian stage	20

The peculiar physical character of the lower bowlder clay is striking. It is dense, and breaks usually in flakes rather than joint blocks. It is of a strikingly dark color. There are few joint cracks and these show no special signs of weathering. The sharpness of the contact between the gravels and the bowlder clay with the presence of many hard pebbles indicates apparently one of two things (1) either this lower clay was not exposed to surface action before the gravels were laid down or (2) it was so vigorously eroded immediately before the deposition of the gravels as to cut away all evidence of former surface exposure. The balance of probabilities between the two will be discussed later.

Thayer Section. The Thayer section is of interest since it seems that here the evidence of two drifts was first detected. The section as now shown varies a little from point to point in the pit, but a representative exposure shows the following beds:

		Feet.	Inches.
9.	Black soil		6
8.	Reddish gravelly clay (ferretto)	1	
7.	Yellow bowlder clay becoming gravelly below and containing quartzyte, greenstone and granite; flattened and striated pebbles with lime concretions	10-20	
6.	Fine sand	1	6
5.	Drab to blue pebbly clay with sticks and bits of undetermined wood	4	
4.	Fine sand	3	
3.	Drab pebbly clay as above	12	
2.	Fine sand	2	
1.	Gravel as seen before, stratified and cross-bedded; pebbles mainly less than 1 ½ inch in diameter but with some large bowlders. Material of the usual Kansan facies, much weathered and highly colored	15-20	

Summarizing the above we have the loess and yellow and blue clay phases of the Kansan with the underlying gravels. The blue clay phase of the Kansan is unusual in the presence of interstratified beds of fine sand and the abundance of woody material. It is dark and might readily be taken for a buried soil, but it is believed that this is not the true interpretation. The exposure does not now show the beds as seen by Messrs. McGee and Chamberlin. The same horizon as exposed some feet eastward shows merely the blue black pebble clay as mentioned above. The presence of so much wood in the bowlder clay is difficult to explain unless it be regarded as basal, and the beds as now exposed have no thoroughly satisfactory explanation on either hypothesis. Regarding the clay, however, merely as the blue clay phase of the Kansan

the whole series of phenomena become concordant and consistent and in the question of the presence or absence of a distinct sub-Aftonian till sheet the beds to be considered lie all at one horizon—below the gravels.

There are certain concordant phenomena which must be kept in mind in framing a hypothesis to explain the Afton exposures. The gravels themselves are exposed at several points. A peat bed is found in wells near Afton, and forest beds are found near Lamoni, Murray, Fontanelle, Washington, Sigourney, and at various points in Taylor county, Iowa, and Harison county, Missouri. The peculiar blue black bowlder clay is occasionally exposed throughout the state. There is a gumbo between drifts at points in Clarke and Decatur counties, and an old soil shows on Grand river. The exposure near Hastie, in Polk county, is considered very significant.

Summary.

In considering the conclusion to be drawn from the evidence now in hand the remarks relative to the value of the various lines of evidence should be kept in mind.

First. It is submitted that there is widespread evidence of buried forest and peat beds in the region. It is admitted that nothing of importance bearing on the character of this flora as regards climate is known. It is further admitted that these notes on forest beds have not been sifted and much of the evidence is of uncertain value. It is on the other hand to be noted that certain of the beds are well attested as to position, occupying a horizon fitting well with the hypothesis of two drifts and that some are of a thickness worthy of consideration. Upon the whole, however, the argument from forest beds probably has little independent value.

Second. Buried soils have been shown to be not unknown, though the value of the evidence derived from them is uncertain.

Third. It has been impossible so far to apply the ordinary tests based on leached and ferretto zones to the sub-Aftonian.

Fourth. Waterlaid beds are present at several points at the Aftonian horizon. In Polk county they are believed to be notably earlier than the overlying drift. At Afton they seem to the writer to represent kame-like aggregations made during the advance of the Kansan. In general the waterlaid beds are such as might have been formed by agencies closely connected with the ice. The possible exception is the buried loess at Afton Junction which, however, would only necessitate a considerable change in the vigor of deposition between the time of its formation and the laying down of the overlying gravel.

Fifth. Since the presumed sub-Aftonian drift is thought to be wholly covered by the Kansan and is certainly known to be in the region studied, there is but little chance to contrast the topographic development of the two drift surfaces. Relative to erosion in the period between the two drift sheets it may be stated that the Hastie exposure strongly favors such a supposition. In considering the matter whether or not the exposures near Afton also favor such an hypothesis

the presence of the buried loess at Afton Junction should not be forgotten. This loess is of the old type, and if, as seems probable from several lines of evidence, the older loess or white clay owes its peculiar properties as much to secondary change as to conditions of original deposition, it alone would show a considerable time interval. At the Grand river exposure it will be recalled that the upper surface of the lower drift showed apparently no signs of either loess or weathering. One would hesitate long before basing any argument upon a local distribution of such loess as occurs in northeastern Iowa, but it is not so hazardous to use such an argument when discussing the older loess. The latter is uniformly widespread over the surface of the Kansan and Illinoian in southern Iowa. Its character gives one some confidence in assigning to water a considerable part in its formation and, inasmuch as the buried loess is of the same type as that now found over the upland, it seems well in accordance with what conservatism demands to expect it to have at least a considerable distribution. Certainly we would look for its presence in the Grand river exposure scarcely a mile away. Its absence then becomes a legitimate argument favoring erosion before the gravels were laid down. One might suggest that this erosion was due to the ice except that in that event one would expect till and not water-laid beds to be the first deposits. Furthermore, while we are becoming able to understand how a glacier may deposit over soft beds without disturbing them, we have as yet no case of glacial erosion of unconsolidated beds leaving as sharp and unmarked a surface as that of the top of the till at the point in question. If then erosion be granted it must be held to have been pre-Kansan, and in view of the freshness of the underlying till, it must have been considerable. Upon the whole this is believed to be the best explanation of the phenomena.

Sixth. It has been shown that there are exposures in the region of a drift of peculiar physical type; that this drift is wholly unlike any known phase of the Kansan, and that in every instance there are some independent phenomena favoring the hypothesis that it is distinctly older than the Kansan. Whatever one may think of correlations based upon physical characters, these facts are certainly of some significance. Furthermore the same facts are true of the known exposures of the presumed pre-Kansan drift at Muscatine, Oelwein, Albion, and indeed throughout the state.

General conclusion. It is believed that the argument for a pre-Kansan drift sheet derived from erosion is strong and that it has independent value. The arguments from other sources tend to greatly strengthen it, and the cumulative force of the whole is believed to be sufficient to put the burden of proof upon those, if any, who would attempt to deny the existence of pre-Kansan drift. All would, however, probably agree to the statement which the writer believes warranted by the evidence in hand, and which he expects future investigations to amply confirm, but for anything beyond which there is probably as yet no sufficient

evidence, that *there are in Iowa traces of a drift sheet older than the Kansan and separated from it by an unknown but probably considerable interval.*

It may be mentioned in conclusion that it has been suggested, notably by Chamberlin,* that a complete series of deposits recording a glacial period should theoretically include a series of early minor advances culminating in a period of maximum glaciation, followed by a second series of advances of decreasing intensity. We have for some time faced the anomaly that the earliest glaciation of which we had record was that of showing the maximum extent of the ice. The pre-Kansan fills in the gap and answers apparently to one of these earlier and minor stages of advance. Additional work along the extreme drift border may possibly prove that the pre-Kansan extends out beyond the limits of the Kansan, but this is considered improbable. It is to be noted that according to the theory there should be more than one pre-Kansan advance and partial retreat of the ice, just as we have several post-Kansan ice sheets. These earlier drifts may or may not have been separated by notable intervals as in the case of the later drifts. It is quite possible that the pre-Kansan we now know of is not all one thing, and for this reason, as well as the incompleteness of our knowledge of it, it seems best that this earlier drift should not be given a definite formational name, certainly not until more is known of it. For the present, the term pre-Kansan may be used, and just as pre-Cambrian, in a much older portion of the geological column has come to have an accepted meaning, it is believed that the term will be valuable. The pre-Kansan of Iowa may or may not belong with the Albertan of Dawson. It may be older or younger. Probably we shall never know very much about its divisions, though we may justly expect to know much more of its distribution and character. It should be noted that the original correlation of the forest bed of eastern Iowa with the Aftonian deposits proves now to be essentially correct, since the former includes deposits both above and below the drift now known as Kansan. Possibly further study may indicate the advisability of a return to original nomenclature, though that outcome is not thought to be probable.

H. FOSTER BAIN.

SOME PREGLACIAL SOILS. [Abstract.]† In the region south of the Wisconsin driftless area an old soil is occasionally found under the Kansan drift, generally resting on bed rock, and often associated with laminated, water-bedded clay and other silt. An exposure of such a soil occurs under a bluff of drift in the southern part of Muscatine, Iowa. The material here is dark brown in color, mottled with small black fragments of vegetable tissue. The upper part is a dark mucky clay. The whole bed is only two or three inches in thickness. It lies below what appears to be pre-Kansan drift. A similar bed was uncovered on the east side of Eastern avenue at Davenport, Iowa. This

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*Great Ice Age (Geikie), p. 736, 1895.

†Read before the Iowa Academy of Sciences, Dec. 1897.

bed is somewhat darker than that at Muscatine. At Rock Island, Illinois, the same bed has been encountered in several wells. In one of these, near the crossing of Thirty-fifth street and Seventh avenue, the materials penetrated consisted of loess, apparently two sheets of till, silt varying from a black to a grayish loess, with small gasteropods, and then a greenish, sticky clay containing fragments of the bed rock, but apparently no Archean pebbles or bowlders. This latter clay was five feet in thickness and rested on shales and clays of the Coal Measures. It seemed to be residual material of preglacial age. The silt and muck above it contained fragments of wood, one of which measured nearly two feet in length. Silt of the same and in the same position, but oxidized and without fragments of wood, has been exposed in grading some of the streets near by. On Thirty-ninth street it contained the following fossils: *Helicina occulta* Say, *Pupa alticola* Ingersoll, *Pyramidula striatella* Anthony and *Succinea avara* Say. Similar deposits, without fossils, occur under the drift in the bluffs east of Cordova, Illinois, and in the northern part of Clinton, Iowa. At the latter place they are finely laminated and are associated with a peaty or soil-like layer. A deposit which appears identical with the loess-like silt on Thirty-fifth street, Rock Island, is found underlying till on the east line of section 12, T. 17 N., R. 1 W., south of the city, and another occurs in the bluffs of the Mississippi river in the west end of the county. At the first of these localities the deposit rests on Coal Measures and contains the fossils already mentioned as occurring at Thirty-ninth street. At the exposure in the west end of the county the underlying beds are not seen. The total thickness of the overlying drift is about 100 feet. Shells are abundant, and according to the determinations of Dr. W. H. Dall they include *Helicina occulta* Say, *Helicodiscus lineatus* Say, *Limnæa humilis* Say, *Pupa armifera* Say, *Pyramidula perspectiva* Say, *Pyramidula striatella* Anthony, *Strobilops labyrinthica* Say, *Succinea avara* Say, *Succinea luteola* Say, *Polygyra*, sp., *Vitræa arborea* Say.

These loess-like deposits have a bluish green color in fresh exposures, but one season of weathering gives them a reddish gray hue to the depth of one or two feet, and then their resemblance to the loess in color as well as in structure is quite marked. Even the tubular, ferruginous concretions of the latter deposit appear.

The precise relation of the soil beds to this deposit and to the laminated silts with which it seems to be associated, and the relation that the two latter have to each other, can not be fully made out from the known exposures. In the well on Thirty-fifth street there seemed indeed to be two soil horizons. The section under the Kansan till was as follows, beginning above:

1.	Black sticky muck with large fragments of wood	4 feet.
2.	Loess-like, ash colored material, with pulmonate fossils.	8 "
3.	Black Muck	4 "
4.	Residual clay full of local rock fragments	5 "
5.	Coal Measures	(Exposed.)

All the fragments of wood found in the ancient soils belong to gymnosperms, and this may be regarded as indicating a boreal climate, such as would precede the advance of the ice. The position of the deposits under the till indicates that they are pre-Kansan in age and possibly preglacial. The region in which they occur lies to the south of the driftless area, where the abrasive work of the ice seems to have been small in amount. Erosion contours of two or three hundred feet in elevation lie buried under the drift in this region, and glacial scorings are unknown. Among such surroundings it would be more singular that preglacial surface deposits should be wholly absent than that they should occasionally come into view.

J. A. UDDEN.

Rock Island, Ill.

PERSONAL AND SCIENTIFIC NEWS.

ELSTON HOLMES LONSDALE died March 7th, after a brief illness at his home in Columbia, Missouri. Mr. Lonsdale was for a number of years connected with the geological surveys of Missouri, Iowa and the United States. He was born in 1868, attended the schools of his native town, and afterwards entered the State University of Missouri, from which he was graduated in 1889. During his college course he was associated with Prof. G. C. Broadhead, and from this pleasant association decided to enter into geological work. Upon the organization of the Geological Survey of Missouri an appointment as aid was received. Mr. Lonsdale continued his connection with the Missouri organization three years, when he received a call to the Iowa Geological Survey which he accepted and at once entered upon his duties, being placed in charge of the investigation of the clays of the state. Upon the reorganization of the Missouri Geological Survey in 1894 Mr. Lonsdale was asked to accept the post of assistant state geologist. Resigning at the end of one year to take up other work, he became connected with the U. S. Geological Survey, in the topographic service, a position which he held at the time of his demise.

Mr. Lonsdale's work was chiefly in topography and economic geology. His topographical maps are models of careful and painstaking effort, showing a wealth of detail and keen perception of topographic form. His knowledge of geology gave him an insight into the real meaning of relief that few possess; and his skill in cartographic expression of the physiographic features of the regions in which he worked can only

be fully appreciated by those who personally visit the fields.

In his more strictly geological work the constructional materials received most attention. While in Missouri he mapped, in conjunction with Dr. Haworth, large areas of the crystalline district in the southeastern part of the state; located and took copious notes on a large number of iron deposits, being associated with Mr. Nason in this work; and collected much information on the clays and building materials, which was intended finally to form an elaborate report on those subjects. In Iowa his main efforts were directed towards collecting data for an exhaustive report on the clays of the state. The vast amount of information attained regarding the deposits, their character and properties, and the condition of the industry attest the vigor with which his work was prosecuted, and the enthusiasm which the work aroused in him. The work in connection with the U. S. Geological Survey was entirely topographical, the fields of operation being in Missouri, Minnesota and Indian Territory.

Mr. Lonsdale contributed a number of articles of great value to the trade journals. His more strictly scientific papers have appeared in the proceedings of the learned societies and the reports of the geological surveys. The beautiful topographic map of the Mine la Motte district and a part of that of the Iron Mountain area, Missouri, are his work. The "Geology of Montgomery County, Iowa" is the first detailed geological work ever undertaken in western Iowa. The main work of his life on the "Clays of Iowa," which would have occupied a large volume, was not finished at the time of his death.

Mr. Lonsdale was a member of a number of scientific and engineering societies, and was usually in attendance at the meetings, in which he took an active part. C. R. K.

GOVERNMENT EXPLORATIONS IN ALASKA.—The work in Alaska during the coming summer, under the direction of the United States Geological Survey, will be divided between four parties, each of which will conduct geological and topographical investigations. The arrangements for the parties are in general charge of Mr. G. C. Eldridge. The parties are as follows: (1) Mr. G. C. Eldridge, geologist, in charge, and Mr. Muldow, topographer. They will explore the Sushitna drainage. (2) Mr. J. E. Spurr, geologist, in charge, and Mr. Post, topographer. They will explore the Kuskokwim drainage. (3) Mr. Peters, topographer, in charge, and Mr. A. H. Brooks, geologist. They will go up the White river and down the Tanana river. (4) A topographical party in charge of Mr. Barnard. This party will make a more detailed sur-

vey of the Forty Mile district. Mr. Arthur C. Keith, geologist, will coöperate with Mr. Barnard's party in this district.

In addition to these parties two geologists from the United States Geological Survey, Messrs. F. C. Shraeder and W. C. Mendenhall, will accompany expeditions sent out by the War department. It is expected that the first of these gentlemen will go up the Copper river, and that the second will proceed inland between the Copper and Sushitna rivers. All of the above mentioned gentlemen expect to return to Washington the coming fall.

NEW YORK ACADEMY OF SCIENCES. Section of Geology and Mineralogy, March 21st, 1898. The paper of the evening, illustrated by lantern, was by Dr. Heinrich Ries, entitled, "The Clay and Kaolin Deposits of Europe." Dr. Ries sketched briefly the geographical distribution of the kaolin deposits, and their relation and comparison to similar deposits of America. He then gave special attention to the deposits of Great Britain, Belgium, Denmark, Germany and Austria, and mentioned briefly those found in other regions. He described particularly the deposits of Cornwall, which are found in association with veins of tin in granite areas, where it is supposed that the feldspar has been changed to kaolin through the influence of fluoric fumes rising from below. These products are very pure, containing 97½ per cent of clay substance. He also spoke of the ball plastic clays found in southwestern England, which occur in lenses in large beds of sand, and are used to mix with non-plastic kaolins. Refractory clays are found in England and Scotland in the Carboniferous rocks and are worked by underground mining. Impure clays, used for bricks, are particularly found in the vicinity of London. The Staffordshire blue brick, Fuller's earth and Bath brick deposits were sketched briefly, and the technological treatment in Great Britain, Germany and the United States was compared. The latter part of the paper was devoted to a rapid summary of the position, quality, uses and manner of mining of the famous clays of Bornholm, Denmark; of the Glasspot clays of southeastern Belgium; of the kaolin deposits of Limoges, France, and the deposits of Prussia.

Prof. Henry F. Osborn described the progress made this year, through international effort, in correlating the larger divisions of the fresh water Tertiary deposits of Europe by a study of the vertebrate remains.

Prof. James F. Kemp was elected chairman of the section, and Dr. Heinrich Ries secretary, for ensuing year.

RICHARD E. DODGE, *Sec'y.*

FREDERICK HAWN.

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MAJOR FREDERICK HAWN.

By G. C. BROADHEAD, Columbia, Mo.

[Plate XVI.]

Forty years ago the name of Maj. Frederick Hawn was often heard in geological circles. He was born in Herkimer county, New York, January 5, 1810, and died in Leavenworth, Kans., January 31, 1898, aged 88 years. He was of Revolutionary German stock, his grandfather, Conrad Hawn, having been killed in the battle of Oriskany. He devoted his early life to civil engineering, and assisted in constructing the first railroad in Pennsylvania, and in 1831 saw the first locomotive placed on its track.

In 1835 he was engaged in railroad construction in Illinois, but soon after settled in the town of Weston, Missouri. In 1851 he was engineer on the Hannibal and St. Joseph railroad, but soon after was appointed by Prof. G. C. Swallow as an assistant on the Missouri Geological Survey, and assigned to the duty of making an examination of the country along and near the line of the Hannibal and St. Joseph railroad. He made partial examinations of twelve counties of Missouri near the railroad line from the Mississippi to the Missouri river. The report was published in Swallow's geological report of Missouri, 1855. It called particular attention to the lands and the valuable coal beds near the railroad, and its circulation greatly assisted the railroad company in

the sale of its lands, and thus enabled the company to complete its road at an early day.

Soon after, Maj. Hawn assisted in the linear surveys in Kansas. While thus engaged he took careful notes on Kansas geology, being really the pioneer in that field, and brought together a very interesting collection of organic remains. These were brought to Columbia and carefully studied with Prof. Swallow, and on February 22, 1858, Prof. Swallow, in a communication to the St. Louis Academy of Science, announced the discovery of the Permian in Kansas, and at the same meeting Prof. Swallow offered a paper for publication entitled "The Rocks of Kansas," by G. C. Swallow and F. Hawn. This was published in Volume I. of the Transactions of the Academy, pages 173 to 198. In the same volume of Transactions, pages 171 to 172, Maj. Hawn contributes a paper on the Trias of Kansas. This was the first announcement of such beds being found in Kansas.

The series of fossils collected by Maj. Hawn in Kansas awakened great interest in western geology, and soon after Meek and Shumard also published papers on the Permian.

Between the years 1865 and 1870 Prof. Swallow was state geologist of Kansas, with Hawn assisting in the work. Swallow says (letter of Transmission, Jan. 8, 1866): "Maj. Hawn has given the survey the full benefit of his intimate and extensive knowledge of the state and its resources. His reports are full of scientific and practical information." Swallow's geological report of Kansas includes Hawn's report of 25 pages, with brief notices of the geology of the counties of Linn, Chase, Doniphon, Brown, Greenwood, Lyon, Butler, Osage and Morris.

In 1853 Lieut. E. H. Ruffner, corps of engineers U. S. A., under the direction of the war department, made a reconnoisance of the Ute country in southwest Colorado. Maj. Hawn accompanied the expedition as geologist and meteorologist, and Lieut. Ruffner, in his report to the war department, says of Hawn, "That Professor Hawn has been as faithful to his trust as could be desired is undoubted, and that little has escaped his eye is a natural consequence of his untiring industry. I speak decidedly in giving my testimony to the efficiency of the geologist's assistant, L. Hawn. I beg to

state that although I have slightly altered the form of the geological report I have endeavored to change nothing in its sense." In his geologic work Maj. Hawn was assisted by his son, Laurens Hawn.* Hawn's report accompanied that of Ruffner's, and includes a geological reconnoisance along the route, as well as a report on the Ute country, list of mines, fossils, rocks and ores.

Maj. Hawn's letters to the eastern papers during the infancy of Kansas assisted very much in drawing immigration to the territory. Following his advice prospecting for coal was done at Leavenworth, and a shaft sunk and coal obtained, and now, for a number of years, Leavenworth has been a distributing point for coal and the city has prospered.

Maj. Hawn, through life, was more or less a student of science, his later life being chiefly devoted to meteorology, and independently of others he showed conclusively that hot air waves were not generated by surface heat in their path, but by the bearing down or descending air evolving heat by pressure.

Maj. Hawn was a quiet, modest man, and the later years of his life were spent in retirement with his family, delighting in his fruits and flowers. The day before his death he completed an article on meteorology for Colman's Rural World. Although he gradually became more feeble in body as he grew older, yet his mind was bright to the last.

GEOLOGICAL PUBLICATIONS OF FREDERICK HAWN.†

[Report on country between the Mississippi and Missouri rivers near the line of the Hannibal and St. Joseph railroad.] Geol. Survey of Mo., 1st and 2nd Ann. Repts., pt. 2, pp. 121-136, 1855.

The Trias of Kansas. St. Louis Acad. Sci., Trans., vol. 1, no. 2, pp. 171-172, 1858.

The rocks of Kansas. By G. C. Swallow and F. Hawn. St. Louis Acad. Sci., Trans., vol. 1, no. 2, pp. 173-197, 1858.

[Report on Brown, Doniphon, Chase, Linn, Greenwood, Lyon, Butler, Osage and Morris counties, Kansas.] Geol. Survey of Kans., Swallow's Preliminary Report, pp. 97-122, 1866.

[Report on the geology of the Ute country, etc., in southwest Colorado.] Report of reconnaissance in the Ute country, made by Lt. E. H. Ruffner in 1873; pp. 59-89, 1874. 1st session of 42nd Congress.

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*Now probate judge, Leavenworth, Kansas.

†Prepared by his son, Judge Laurens Hawn.

GEOLOGY OF THE ST. CROIX DALLES. III.

By CHARLES P. BERKEY, Minneapolis.

(Plates XVII-XXI.)

PART III. PALEONTOLOGY.

CHAPTER I. *Review of the Fauna.*

Since the publication of the reports of Owen* and Hall† upon this and neighboring localities, there have been few additions to the fauna of the lowest rocks of the upper Mississippi valley. The most notable exception to this statement is the work by Whitfield.‡ This period of comparative inactivity is the result of the greater immediate demand for investigation in other directions rather than any tendency to consider this field exhausted. In this connection it is interesting to read the words of Hall from his general summary (op. cit.) of the faunas of this region. He says: "Whenever this locality, and the region about it, shall be more fully investigated, we may confidently predict that additions of much value and interest will be made to the primordial fauna of the Upper Mississippi valley." P. 180.

A protracted search in the last two seasons has revealed an extensive group of fossils many of which are believed to be undescribed. These forms belong to the Basal Sandstone series and, in order that a better understanding of their relationship may be secured, a summary of the species previously described from overlying strata is here added.

Magnesian Series. The uppermost representative of this series within the district is the *Jordan* sandstone. The following species are found in this formation.

Bellerophon antiquatus Whitfield.
Pleurotomaria (*Holopea*) *sweeti* (Whitfield) Sar.
Ophileta sp. (?)
Murchisonia sp. (?)
Lingula stoneana Whitfield.
Orthis pepina Hall.
Raphistoma minnesotense (Owen) Sar.
Tryblidium (*Metoptoma*) *barabuensis* (Whitfield).
Agnostus disparilis Hall.

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*Owen: Geol. Surv. of Wisconsin, Iowa and Minnesota, 1852.

†Hall: 16th Rep. N. Y. Mus. Nat. Hist., 1863.

‡Whitfield: An. Rep. Geol. Surv. of Wisconsin for 1877. Geology of Wisconsin, vol. IV, 1882.

TWO GENERIC TYPES.

Fig. 1. Cheilocephalus st. croixensis, ***n. sp.***

Fig. 2. Hypseloconus recurvus (*Whitf.*), *var.* **elongatus.**

A. parilis Hall.
Aglaspis barrandii Hall.
Dicellocephalus osceola Hall.
Illænurus quadratus Hall.

In addition to these, many fragments of trilobites of undetermined species are found. Osceola, Wisconsin, and Rapidan, Minnesota, are well known localities. Within the district besides the Osceola occurrence, there are a few trilobite fragments to be found in the sandstone conglomerate mentioned in a former chapter as the most northern outcrop of the Jordan sandstone.

From the *St. Lawrence* shales the following have been reported.

Dicellocephalus minnesotensis Owen.
D. pepinensis Owen.
D. spiniger Hall.
Lonchocephalus chippewaensis Owen.
Ptychoparia anatina Hall.
P. diademata Hall.
P. eryon Hall.
P. oweni Hall.
Lingula aurora Hall.
L. mosia Hall.
L. winona Hall.
Orthis pepina Hall.
Euomphalus vaticinus Hall.
Raphistoma minnesotense (Owen) Sar.
Serpulites murchisoni Hall.

The principal localities from which fossils have been described are Marine Mills, Trempeleau and La Grange mountain.

The remarkable group of fossils from near Baraboo, Wisconsin, referred to the Lower Magnesian by Whitfield*, evidently, as suggested by Irving†, belong to a lower horizon. They will be discussed in more detail in another chapter.

The Basal Sandstone Series.

In Wisconsin to the southeast of this area the floor of the basin in which Cambrian strata lie is occupied by a great sandstone bed. This is followed by a series of shales above the middle of the formation, which series is in turn succeeded by

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*Geology of Wisconsin, vol. IV, 1882, p. 194.
†Geology of Wisconsin, vol. II, 1877, p. 537.

another sandstone reaching to the base of the Mendota* (St. Lawrence). The average relative thickness is estimated to be:

Lowest sandstone, 300 feet.
Middle shales (Dresbach), 100 feet.
Upper sandstone (Franconia), 150 feet.

A similar succession is indicated in Minnesota by such evidence as the boring of deep wells affords. The series of shales and upper sandstones are well exposed and present sufficient distinctness to allow subdivision. The lowest representative of the Cambrian strata in the Northwest, the lowest formation of the Basal Sandstone series, attaining a great depth on the floor of the Pre-Cambrian basin, is not exposed at any point within the St. Croix Dalles area. Therefore the fauna of these strata seen at Taylor's Falls and vicinity does not represent the earliest faunal characters of the Cambrian as it is developed in Wisconsin and Minnesota. The lowest sandstone member doubtless carries a fauna as characteristic as other divisions of the formation. What variation there may be is not yet known.

The Franconia sandstone includes the third trilobite bed of Owen. Several species described by Hall also clearly belong to this formation. The following species are reported from Franconia, Minn.:

Agraulus (*Arionellus*) *bipunctatus* Shumard.
Crepicephalus (*Conocephalites*) *diadematus* Hall.
Dicellocephalus misa Hall.
Hypseloconus franconiensis, n. sp.

Other localities have added:

Agnostus josepha Hall.
Chariocephalus whitfieldi Hall.
Crepicephalus miniscensis Owen.
Dicellocephalus misa Hall.
Lonchocephalus hamulus Owen.
L. wisconsensis Owen.
Ptychaspis (*Dicellocephalus*) *granulosa* Owen.
P. (*Dicellocephalus*) *miniscensis* Owen.
Ptychoparia (*Conocephalites*) *anatina* Hall.
P. (*Conocephalites*) *nasutus* Hall.
P. " *patersoni* Hall.
P. " *perseus* Hall.
P. " *shumardi* Hall.

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*Geology of Wisconsin, vol. I, p. 121, 1883.

The principal localities are Franconia, Chippewa river, Trempeleau, Minneiska, Black river, Marine Mills and Kickapoo river.

Fossils from this formation are poorly preserved. No part of the shell is present and this sandstone is so friable as to render the casts which alone represent the fauna extremely fragile materials to work upon.

The Dresbach sandstones and shales are in great contrast to the Franconia sandstone. Whereas in the Franconia formation there are no shells and few casts; on the contrary, in the Dresbach shales immediately below they are so abundant that a single hand specimen from a favorable point contains hundreds of fragments of brachiopod shells. The range of species is limited and the considerable addition which is made in this paper as to variety of forms has not indicated a very extended geographic distribution. These new forms are described in a later chapter. Fossils reported from the Dresbach at Taylor's Falls and St. Croix Falls are:

Lingula ampla Owen.
L. antiqua Hall.
(*Lingulepis pinniformis* Owen.)* *Lingulepis acuminata* Con.
Obolella polita Hall.

In addition to these the following were found recently by me:

Hyalithes primordialis Hall.
Hypseloconus (*Metoptoma*) *recurvus* (Whitfield).
Agraulus convexus Whitfield.
Ptychoparia calymenoides Whitfield.

and a considerable number of new species which are described in a following chapter. Other localities have reported the following species from this horizon:

Crepicephalus (*Conocephalites*) *eos* Hall.
Dicellocephalus iowensis Owen.
Ptychoparia (*Conocephalites*) *minor* Shumard.
Hyalithes primordialis Hall.
Platyceras primordialis Hall. (*Scævogyra* probably.)

In addition to these foregoing species noted with comparative certainty under their respective formations, there are a

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*A recent article by C. D. Walcott makes *Lingulepis pinniformis* Owen a synonym for *Lingulepis acuminata* Con.

number whose horizons are so uncertain or so poorly defined that any attempt to limit them to a definite formation is largely a matter of conjecture. They are therefore grouped in a list by themselves with this explanation, that they probably represent a vertical range from the Jordan sandstone of the Magnesian series down to the lowest beds of the Basal Sandstone series.

Palæophycus plumosum Whitfield.
Aglaspis etoni Whitfield.
Agraulus woosteri Whitfield.
A. (*Arionellus*) *convexus* Whitfield.
Crepicephalus gibbsi Whitfield.
C. onustus Whitfield.
Ellipsocephalus curtus Whitfield.
Dicellocephalus lodensis Whitfield?
D. latifrons Shumard.
Ptychaspis barabuensis Winchell.
P. (*Conocephalites*) *quadrata* Whitfield.
P. minuta Whitfield.
P. striata Whitfield.
Arenicolites woodi Whitfield.
Leptæna barabuensis Whitfield.
Triplesia primordialis Whitfield.
Ophileta (*Straparollus*) *primordialis* Winchell.
Pleurotomaria advena Winchell.
Scolithus linearis Hall.

The remarkable group of fossils from Eikie's quarry, near Baraboo, Wisconsin, bears such a striking resemblance to the new forms from the Dresbach at Taylor's Falls that it seems most proper to enumerate them here. Notwithstanding the difficulties of stratigraphy at Baraboo and the inclination of the Wisconsin geologists to place them much higher in the series of formations, it is at least clear that the two faunas are in all essential respects similar. The Baraboo fossils are:

Leptæna (*Orthis*) *barabuensis* Winchell.
Euomphalus strongi Whitfield.
Tryblidium (*Metoptoma*) *barabuensis* (Whitfield).
T. (*Metoptoma*) *similis* Whitfield.
T. (*Metoptoma*) *retrorsa* Whitfield.
Hypseloconus (*Metoptoma*) *recurvus* (Whitfield).
Scævogyra elevata Whitfield.
S. obliqua Whitfield.
S. swezeyi Whitfield.

Dicellocephalus barabuensis Whitfield.
D. etoni Whitfield.
Illænurus convexus Whitfield.

CHAPTER II. *Additions to the Fauna.*

The greater part of the sedimentary strata in this area is made up of porous friable sandstones and shales unfavorable for the preservation of organic remains. Calcareous portions of the lower Dresbach shales are, however, favorable for preservation and in them are crowded great numbers of *Lingulepis pinniformis* and related forms. Certain portions of the green-sand horizon also are packed with the broken fragments of shells. Although fragments are so abundant it is almost impossible to obtain specimens from the green-sand bed sufficiently well preserved to be identified. Portions of the finer grained sandstones still preserve the imprints of numerous forms, although in most cases no trace of the original shell remains. These occurrences are always limited in extent, and consequently in many outcrops they are not to be found at all. One of the most promising localities for fossils is Lawrence creek gorge at Franconia, from which several good fossiliferous slabs were taken. The marginal conglomerates have proved most fruitful, and recently a fauna has been discovered in these conglomerates which is unique. Several new species and a few rare types are included in it. The general character of the fauna is essentially that represented in the Baraboo fossils described by Whitfield in Geology of Wisconsin (loc. cit.). Over a hundred specimens have been obtained and the range of variability which they exhibit throws some light upon classification of the early forms of gastropods. The gastropods are almost wholly of the conical type with oval aperture. They thus belong to *Tryblidium* and related genera.

Principles of Classification.—Of the total number of species credited to the Cambrian, 65 per cent belong to the distinctly conical shells. Moreover twenty species of cone-shaped mollusks classed with the Pteropoda are placed in the Cambrian, so that of the whole number of species of all related forms, 80 per cent are distinctly conical in outline. In accordance with evidence gathered from the descriptions of

these primitive types and the detailed study of considerable material the following statements may be conceded to have the support of all facts at hand.

Nothing is known as to the real nature or internal structure of the earliest forms classed as gastropods, and in the absence of biologic evidence the only rational basis of classification is that of variation in form.

Results based upon material of exceptional value for such investigation, and a tentative recast of the related forms described from the Cambrian, lead to the conclusion :

1st, that the simple symmetrical cone was probably the earliest form of gastropod.

2nd, that this form is represented by a group of fossils whose specific variation consisted in:

a. Variation in hight.
b. Variation of aperture in shape between the circle and symmetrical ellipse.
c. Variation in striation, growth lines and radial striæ being at most only specific characters and subject to obliteration in the process of fossilization.
d. Variation in thickness of shell.

Following the line suggested by a study of the material in hand there seems to be two steps in variation exhibited:

1st, a tendency to acuminate aperture followed by or accompanied by excentricity of apex.

2nd, a tendency to a more irregular aperture usually more or less triangular or notched followed by or accompanied by more or less excentricity of apex.

The first of these lines of variation gives rise to two divergent branches: 1st, those anteriorly (acuminately) inclined; 2nd, those posteriorly (obtusely) inclined or recurved. The first is the *Tryblidium* type. The second is typified in a new genus *Hypseloconus*.

Specific distinctions are chiefly questions of

a. Size.
b. Comparative excentricity of apex.
c. Apical angle.
d. Striations of all kinds.
e. Variation from typical aperture.
f. Comparative curvature of the sides.

These two lines of variation are valid morphologic grounds for generic distinction and division. They exhibit an unbroken series of forms leading to independent but perhaps closely related genera. Regarding internal muscle scars it is evident that a statement recently made in a work upon this subject by Mr. Ulrich needs revision. His statement is essentially as follows:* An examination of all forms on which muscle scars are known supports this biologic or structural law that:

1st, all forms in which the muscle scars are interrupted are anteriorly (acuminately) excentric.

2nd, all forms in which the muscle attachment is continuous are posteriorly (obtusely) excentric, i. e., the apex inclines toward the larger rounded margin of the aperture.

Notwithstanding this general statement by Mr. Ulrich, I must insist that it does not apply to the forms to be described. Paired muscle scars have been detected in both lines of variation. A few of the obtusely inclined forms show the marks so well and are at the same time such typical specimens of their own group that no rule of such sweeping generalization could be formulated, especially since most primitive types show nothing for or against such conclusions.

Faunal Relationships.—There have been no less than nine different generic names proposed for the simple cone-like shells which occur fossil in Palæozoic rocks. Among these most all possess characteristics either of form or muscle attachment sufficiently constant to hold an independent place in classification. A few of them, however, seem to be based upon characters of too questionable value for generic distinctions, notwithstanding their apparent value in distinguishing species or varieties or individuals. Such a character, for example, is that of surface marking. With the large number of specimens in hand it seems to be shown in these forms, as has been long known in many others, that fine or coarse striation either radially or concentrically or even strong plication are characters of comparatively little taxonomic importance. Among the obstacles to a correct adjustment is the magnified apparent discrepancies of type arising from great differ-

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*Geol. and Nat. Hist. Surv. of Minn., Final Rep., vol. III, part II, 1897, p. 828.

ences in size and state of preservation, e. g., between certain species referred to *Tryblidium* and some of the forms referred by authors to *Stenotheca* it is difficult to describe a satisfactory difference beyond the fact that one is twenty times the size of the other, although a glance would seem to be sufficient to separate them.

The tendency among American paleontologists until recently was to place many unlike forms in the genus *Metoptoma*, Phillips, 1836. Since 1872, however, as new forms have been studied, distinctions have been made which allow of a considerably more complete subdivision.

The *Metoptoma* type is truncated under the apex and has a horse-shoe shaped muscle scar. These two points together serve to distinguish the genus. No materials in the Taylor's Falls collection belong to this genus.

Lepetopsis, Whitfield, 1882, is from later formations and is sufficiently well distinguished from all of the more primitive types by its dextrally coiled nucleus.

Scenella, Billings, 1872, includes patelliform shells with circular or oval aperture and subcentral apex. Muscle attachments form a complete circle so far as known.

Stenotheca, (Salter), Hicks, 1872, and *Palæacmæa*, Hall and Whitfield, 1873, may be divisions worthy of generic distinction, but in the present condition of our knowledge they can scarcely be given more than sub-generic rank with any assurance, since surface ornamentation alone cannot be very generally accepted as a generic character.

Conchopeltis, Walcott, 1876, is a lobed form and of so irregular outline and altogether of so uncertain affinities that it need not claim serious attention in a study of the types in hand.

Archinacella, Ulrich, 1897, presents some perplexities. In so far as a continuous muscle attachment coupled with the outline of *Tryblidium* is substantiated by actual specimens there seems to be a place for the genus. But since a majority of the species referred by Ulrich* to this genus do not exhibit well marked muscle attachment of any kind and in addition conform closely in outline either to *Tryblidium* or to

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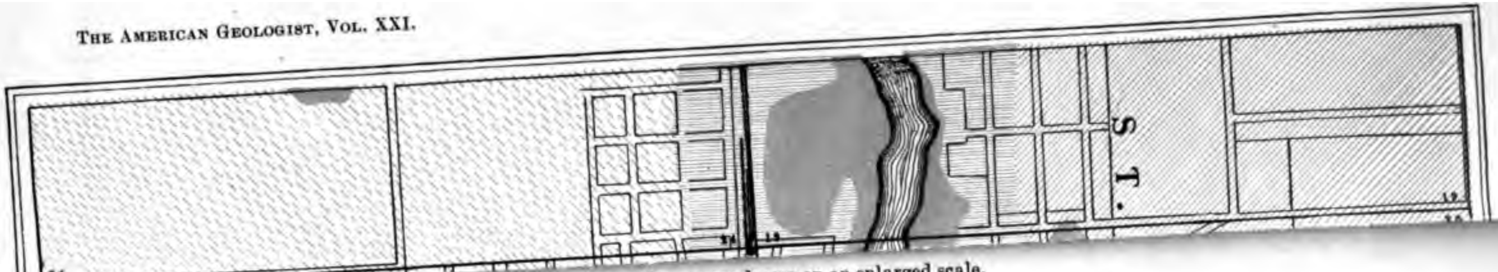
*Geol. and Nat. Hist. Surv. of Minn., Final Rep., vol. III, part II, p. 828.

PLATE XVIII.



An area two miles square drawn on an enlarged scale.

(The Park boundary on the west side of the river is represented by an interrupted line.)

Scenella, there would seem to be reason for setting the term aside for the present in doubt.

Tryblidium, Lindstrom, 1880, is a well defined genus, which as shown by known materials comprises patelliform shells with oval or anteriorly acuminate aperture and with muscle scars forming a circle of six (or more) pairs. The apex of the shell is directed anteriorly, i. e., toward the acuminate margin of the aperture.

Helcionopsis, Ulrich, 1897, is based upon but one character, i. e., fine radiating striæ upon the surface of the shell. It is clearly a *Tryblidium.* The distinction is certainly of no more than specific value.

Another group of which a large number of specimens have been collected during work upon the "Geology of the St. Croix Dalles" comprises conical shells with the apex bent backward. The curve from apex to posterior (broader) margin is therefore concave instead of convex as in *Tryblidium.* Muscle scars are similar to *Tryblidium* as indicated on the casts. This group is in fact united with *Tryblidium* through *T. rectilaterale,* n. sp., but is separated into a new genus because of the direction of development which is toward *Eccyliomphalus* instead of toward *Patella* and on account of the radically different form which at once develops in this line. *T. rectilaterale* again when compared with *Hypseloconus* approaches *H. cylindricus,* n. sp., most closely which is only slightly acuminate and excentric and its musculature is unknown. *H. cylindricus* differs from *Hyolithes* chiefly in its direct non-oblique and oval aperture *T. rectilaterale* has the oblique aperture but not the triangular cross section of *Hyolithes* while *Hypseloconus recurvus,* var. *triangulatus,* has a suggestion of the triangular outline but not the typical aperture. There seems to be indicated altogether a primitive relationship between the *Patellidæ, Euomphalidæ,* and perhaps also a more remote relationship to the *Pteropoda.*

DESCRIPTION OF SPECIES.

GASTROPODA.

Genus **Tryblidium,** Lindstrom, 1880.

In conformity with the facts just noted bearing upon specific variability, it is deemed best to include a greater range of forms within this genus than has been at times customary.

Description. Shell conical, aperture oval, acuminate anteriorly: apex anteriorly excentric, submarginal or extra-marginal; surface smooth or striated, in the later representatives sometimes highly decorated: length of aperture usually exceeds hight of apex: shell variable in thickness: muscular attachment interrupted and the impressions arranged in pairs.

In many of the forms, obtained from the Cambrian rocks especially, no muscle attachment can be located. Those which show such impressions present a circle of paired scars around the cone.

It would be an advantage to be able to limit the genus to a definite number of paired muscle scars. The question has been the subject of some disputes. In the earlier forms which are well enough preserved to show muscle scars the number is six. As it now stands, however, the form of the shell is the chief and almost the only feature offering a basis for a classification of many specimens.

Tryblidium rectilaterale, n. sp.

Plate XX, Figs. 29 and 30. Plate XXI, Fig. 17.

Shell conical: apex erect and anteriorly submarginal: sides straight forming a simple inclined cone: aperture broadly oval, anteriorly acuminate and plane: surface shows strong growth plications: hight, 33 mm.; length about 35 mm.: apical angle 50° x 40°. The specimen is a cast of the interior. Shell thin, as indicated by space between cast and mould. No muscle scars preserved.

Formation and locality: Dresbach. Found in the sandstone filling between boulders of the conglomerate at Taylor's Falls, Minn.

Tryblidium convexum, n. sp.

Plate XX, Figs. 24 and 25. Plate XXI, Fig. 18.

Interior cast conical: apex erect and submarginal, acute, falling just within the anterior margin of the aperture: aperture broadly oval, markedly acuminate anteriorly: dimensions proportioned approximately as follows: Length 40 mm.: hight 20 mm.: width 32 mm.; apical angle 90° x 60°: sides a little convex, except the line from apex to anterior margin, which is almost straight: surface shows traces of growth lines and radial striations: a number of slight elevations and depressions lying in a band, midway between the base and apex of the cone, are taken to indicate muscle attachments. There are traces of six pairs of muscle scars in this form.

This form is apparently very close to *Metoptoma niobe* Billings from the upper Calciferous, Missiquoi, Canada E. (Pal. Fos., I, 1862, p. 37), but is much larger and proportionately very much wider.

Formation and locality: From the Dresbach at Taylor's Falls in the **conglomerate.**

Tryblidium barabuensis (Whitfield.)

Metoptoma barabuensis Whitfield. Ann. Rept. Wis. Geol. Survey for 1877, p. 60, 1878.

Metoptoma barabuensis Whitfield. Geol. Wis., vol. IV, p. 195, 1882.

Metoptoma barabuensis Sardeson. Minn. Acad. Nat. Sciences, vol. IV, part I, p. 97, 1896.

Plate XX, Figs. 18 and 19.

It was first thought that the form described as *T. convexum* above was identical with *Metoptoma barabuensis* of Whitfield, but the following points of difference were considered of too much importance for such identification:

The apical angle of *T. barabuensis* is 70°: the apex also falls outside of the anterior margin, and the posterior slope is quite convex, while the anterior slope is slightly concave. A specimen collected and identified by Dr. Sardeson from Osceola conforms closely to this type, differing chiefly from Whitfield's specimen in the less broadly oval outline of the aperture and the rather strongly developed growth plications.

Formation and locality: The Jordan sandstone, Osceola, Wisconsin.

Tryblidium extensum, n. sp.

Plate XX, Figs. 16 and 17.

Conical shell, inclined far forward so as to project considerably beyond the anterior margin; greatest hight of shell at a point immediately over the anterior margin, equal to 10 mm.; aperture is broadly oval, slightly acuminate anteriorly; posterior slope uniformly more convex than *T. barabuensis*; anterior slope strongly concave; surface closely concentrically striated; length 20 mm.; apical angle about 40°; distance from the posterior margin to apex 26 mm.

This specimen is defective, but is sufficiently complete to allow restoration of all missing parts. It forms an important step in the morphologic series.

Formation and locality: Dresbach. Found at Taylor's Falls in the conglomerate.

This species is similar in general form to *T. exsertum* Sardeson (*Stenotheca exserta* Ulrich) from the Trenton, although it is very differently marked and less acute at the apex.

Tryblidium corpulentum, n. sp.

Plate XX, Figs. 21 and 22.

Shell small, conical; apex obtuse and inclined beyond the anterior margin; posterior slope very convex; anterior slope concave; aperture broadly oval, nearly circular, surface smooth. The convexity of the sides gives this form a decidedly plump appearance. The relative width is much greater than in any of the closely related species. It resembles some described species of *Stenotheca*, but the gradation from this species to the next one, which is clearly of the *Tryblidium* type, is so complete in the specimens at hand that I have no hesitation about its position. Highest part of shell a little forward of the middle, 6 mm.; hight of

apex 4 mm.; length of shell 10 mm.; width 8 mm.; apical angle, large, about 90°.

Formation and locality: The Dresbach at Taylor's Falls in the conglomerate.

This species is near to *T. (Metoptoma) simplex* Billings (Pal. Fos., 1862, vol. I, p. 36), but is more blunt and full toward the apex.

Tryblidium aduncum, n. sp.

Plate XX. Figs. [illegible] and [illegible].

Shell small, depressed, inclined far forward beyond the anterior margin where the apex droops decidedly, and is in two specimens considerably incurved; the acute apex reaches almost to the plane of the base, and the line from apex to anterior margin is sharply concave; posterior slope is broadly convex, becoming uniformly more convex in passing from base to apex; outline from above broadly rounded posteriorly and sharply acuminate anteriorly; aperture similar to this outline, but less acute in front; surface concentrically striated. Some of the specimens referred to this species show in addition a lateral displacement of the apex. Many others showing all essential characters the same are smaller even to one-third the size given. Highest point anterior third, 7 mm; hight of apex about 1 mm; length of aperture 18 mm; width 12 mm; greatest length of whole shell to apex 20 mm. This measurement is from the largest specimen at hand.

Formation and locality: The Dresbach at Taylor's Falls from the marginal conglomerates.

T. (Metoptoma) ovata Billings (Pal. Fos., 1862, vol. I, p. 39), the nearest described species to this form, also shows this lateral tendency, but is of very different proportions and from a later formation.

Genus Hypseloconus, new genus.

Etymology: *hypselos*, high, and *konos*, a cone.

A large number of specimens have been secured which are of the general type represented by *Metoptoma recurva* Whitfield.* A study of these forms side by side with those of the *Tryblidium* type and others has convinced me that they belong to a new genus. The variation in these recurved forms leads to a very different line of development. For example in the *Tryblidium* type, a morphologic series may be arranged in which the forms are more and more depressed at the apex and more convex on the posterior slope but not developing a coil. In the proposed genus, on the other hand, the series passes by easy steps, in which not a single member is missing, to a coil of the [illegible] type. In *Tryblidium* the apex inclines toward the narrower margin of the aperture while in *Hypseloconus* it coils toward the broader margin.

With the excellent material at hand it has been found practicable to group all these forms which curve toward the broader margin of

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*Geol. Wis. vol. IV, p. 170, plate 3, figs. 14 and 15.

the aperture under a new generic name. The forms collected representing this genus are so extremely variable among themselves and even on different parts of the same individual that it has been found inexpedient at this time to subdivide them very closely into species. Accordingly the greater number of specimens are grouped together under the specific name ***recurvus*** already in use as defined by Whitfield. The particular individual or varietal form however which Whitfield described and figured is not considered the best type of the genus. It seems to be an extreme or abnormal individual. Therefore one which is represented by several perfect casts was chosen in its place, (see plate XIX, figs. 1 and 2). I am of the opinion that *M. retrosra* Whitfield is essentially of the *Tryblidium* type and should not be transferred to the new genus. The apex of this specimen is defective and my experience with some of the peculiarities of these types leads me to believe that the recurved character of the apex is overdrawn in the reconstruction by Whitfield. It is believed that *Metoptoma alta* Whitfield, *M. venilia* Billings. *M. orythyia* Billings, and perhaps others should be transferred to this genus.

The shells of all specimens are quite thin. On the only specimen preserving a part of the shell it measures from .25 mm. to .45 mm. in thickness. On many others the original thickness is readily estimated by the separation of the walls of the cast and the results indicated in this way are very little greater than those given above. Variation in size is as great as in any other particular. The largest fragment indicates an aperture of more than 50 mm. through the longer axis. A portion of the cavity once filled by one of these forms has been estimated to require a shell over 100 mm. in length.

Several of these specimens have a well defined slightly depressed area extending completely or almost completely round the cast usually about one-fourth to one-third the distance from the base to apex. The persistence in occurrence and position of this band strongly supports the view that it represents the position of muscle scars of/this genus. On several casts there is a circle of slightly raised areas lying in this position on the cone. On only a few casts are these well preserved but in all such cases the marks are the same in form and position and number. It is therefore added as a character of the genus, —that the muscle attachments form a circle of six pairs of scars considerably above the aperture and parallel to it.

Description. Shell conical, high; apex smooth and more or less curved or recurved toward or even beyond the broader margin of the oval aperture; aperture entire and more or less acuminate anteriorly; surface smooth or striated; muscle scars in six pairs forming a circle parallel to the aperture and about one-third the distance from base to apex.

Hypseloconus recurvus (Whitfield), var. **elongatus,** n. var.

Metoptoma recurva Whitfield. Ann. Rept. Wis. Geol. Survey for 1877, p. 61, 1878.

Metoptoma recurva Whitfield. Geol. of Wis. vol. IV, p. 196, 1882.

Plate XVII, Fig. 1. Plate XIX, Figs. 1 and 2. Plate XXI, Figs. 2, 14 and 21.

Shell conical, very high, upper portion of shell curved very moderately toward the broader posterior margin of the aperture; apex slightly posteriorly excentric, smooth and erect; aperture entire, plane, and a very flat oval in outline, broader posteriorly; length 21 mm; width 16 mm; hight of shell 32 mm; surface bears strong growth plications or fine growth lines or is entirely smooth. Apical angle, 40° x 30°; apical excentricity 5 mm.

Formation and locality: Upper Dresbach, Taylor's Falls conglomerate.

In addition to this particular form there are among these specimens many individuals showing marked differences among themselves but connected in each case by intermediate forms, and whose existence makes further subdivision at this time inadvisable. The more prominent of these individuals are figured in plate XIX. Figures 5 and 6 represent a peculiarity of the anterior slope similar to that noted by Whitfield in *T.* (*Metoptoma*) *retrorsa.* This peculiarity resolves itself however into a mere constriction of the aperture during its later growth and cannot be considered very important. It shows though in addition a more acute aperture anteriorly than most of the specimens. This individual is also represented in plate XXI, fig. 12.

(a) Figs. 3, 4, 7, 8, 21 and 22 are forms intermediate between the type (as represented in figs. 1 and 2) and that figured by Whitfield (as *M. recurva*). These are all recurved, the apex is anterior to the center, but the posterior slope is not nearly so abnormally developed as Whitfield's specimen. Plate XXI, fig. 16, is from a photograph of one of these specimens.

(b) Figs. 29 and 30 represent a specimen with apex much extended. The aperture also is much more rounded than most of the forms. The posterior slope resembles the figure by Whitfield more closely.

(c) Figs. 23 and 24 and also fig. 13 of plate XXI represent two specimens whose anterior slope is irregular indicating a constriction of aperture; and the aperture is noticeably sub-triangular.

(d) Figs. 13 and 14, 15 and 16 represent a few specimens in which the apex is decidedly more excentric even submarginal, and the general appearance of the form gives one the impression that there is a strong tendency to form a coil.

Differences in proportion are apparent by measurements, but these are no more satisfactory in subdivision than the points to which attention has just been called. In studying this fauna it has been found convenient sometimes to refer to the different groups within this species by varietal names. The type specimen (*H. recurvus* var. *elon-*

gatus), group *a*, var. *erectus*, *b*, var. *attenuatus*, *c*, var. *triangulatus*, *d*, var. *marginatus*.

Hypseloconus cornutiformis, n. sp.

Plate XIX, Figs. 11 and 12.

Form high and curved far beyond the posterior margin, forming one quarter volution; surface smooth; curve regular; aperture a flattened oval acuminate anteriorly; hight above base 30 mm; length 18 mm; width 12 mm; apical angle small; apical excentricity 7-10 mm. beyond the broad margin. The apex of the specimen is defective.

Formation and locality: Upper Dresbach, Taylor's Falls.

Hypseloconus capuloides, n. sp.

Plate XIX, Figs. 19 and 20.

Shell small, high, strongly curved equal to one-third volution; surface smooth; aperture entire and much flattened; highest part of shell immediately above posterior margin, extremity curved slightly downward. Hight 10 mm.; length 8 mm.; width 4½ mm.; apical angle small; apical excentricity 2 mm. beyond margin.

Formation and locality: Upper Dresbach, Taylor's Falls.

Hypseloconus franconiensis, n. sp.

Plate XIX, Figs. 17 and 18. Plate XXI, Fig. 10.

Shell small, slender, uniformly coiled to one-half volution; apex smooth, curved downward and slightly inward beyond the posterior margin; aperture defective but apparently entire and oval; surface smooth; hight above base 10 mm.; length of base 8 mm.; apex 5 mm. beyond margin.

Formation and locality: The Franconia sandstone, Franconia, Minn.

This form might possibly be placed with the genus *Eccyliomphalus*. But on account of the series with which it is associated it seems preferable to describe it with them as a representative of one of the extremes of variation in the genus.

Hypseloconus cylindricus, n. sp.

Plate XIX, Figs. 9 and 10.

Form very high, conical, approximating a circular outline of section, but slightly compressed anteriorly; apex absent, but a slight inclination is easily observed; sides almost straight; surface strongly growth marked even to extent of plications; apex subcentral to submarginal. Reconstruction indicates these measurements; hight 25 mm.; length 12 mm.; width 10 mm.; apical angle 20°. A smaller specimen measures 21, 8 and 6 mm.

Formation and locality: Upper Dresbach, Taylor's Falls.

This and the following form might possibly be classed with *Sce-*

nella, but on account of the great hight of shell and resemblance to the preceding forms in everything save the almost central apex and the almost straight sides, I prefer to leave them in this genus.

Hypseloconus stabilis, n. sp.

Plate XIX, Figs. 25 and 26. Plate XXI, Fig. 6.

Form conical, straight, almost imperceptibly inclined toward the broader margin; surface smooth; sides direct; apex central, smooth and blunt; aperture oval; hight 18 mm.; length 14 mm.; width 12 mm.; apical angle 45 °.

Formation and locality: Upper Dresbach, Taylor's Falls.

In addition to these just described a number of coiled forms identified as species of *Euomphalus* and *Scævogyra*, and others whose position is not known, have been found.

Genus **Scaevogyra,** Whitfield, 1878.

One species of this peculiar type was found at the same locality with those already mentioned. Inasmuch as all the species of *Scævogyra* so far described belong to the Baraboo fauna as reported by Whitfield, there is additional evidence in this St. Croix dalles occurrence of the essential identity of the two faunas as a whole and indirectly of the unbroken continuity of the strata to which they all belong.

In comparing these fossils with descriptions of similar forms from the Cambrian strata, one can scarcely escape the conviction that *Platyceras primordiale* Hall* from the "Potsdam group" is not a true *Platyceras* and the same might be said of all species referred to this genus from the Cambrian. *P. primordiale* is with considerable certainty referred to the genus *Scævogyra.*

Scaevogyra minnesotensis, n. sp.

Plate XX, Fig. 26.

Cast of shell showing a sinistral coil of one and a half to two volutions; apex raised just above the body whorl; expanding rapidly; aperture defective but showing an indication of the trumpet form of *S. swezeyi* Whitf. A few lines parallel to the aperture are regular, otherwise smooth.

The elevation, number of volutions, and aperture are sufficient to distinguish it from the known species.

Formation and locality: The Dresbach at Taylor's Falls in the conglomerate.

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*16th Rep. N. Y. Mus. Nat. Hist., 1863, p. 136.

Genus **Euomphalus**, Sowerby, 1812.

Euomphalus strongi Whitfield, var. **sinistrorsus**, n. var.

Euomphalus strongi Whitfield. Ann. Rept. Wis. Geol. Survey for 1877, p. 66, 1878.

Euomphalus strongi Whitfield. Geol. Wis., vol. IV, p. 200, 1882.

Plate XX, Fig. 23. Plate XXI, Fig. 9.

The specimen identified as *E. strongi* presents the characters given by Whitfield in most particulars. These differences however should be noted. Number of volutions one and a half; cross section of body sub-circular, slightly sub-angular at the outer side; inner side decidedly flattened and slightly indented by preceding whorl; coiled a little out of the same plane indicating a tendency to the sinistral spire.

Formation and locality: Dresbach, Taylor's Falls, in the conglomerate. Originally described from Baraboo, Wisconsin, by Whitfield.

Gen.? sp.?

Plate XX, Fig. 20. Plate XXI, Fig. 15.

The specimen represented by these figures was the first one found of the large number from the conglomerates at Taylor's Falls. The figure is from a fragment of a mould and is not complete enough to warrant reconstruction and description. It appears to indicate a tendency to spiral coiling of the dextral type, about one-half volution. It is to be hoped that other and more perfect specimens may be found.

TRILOBITES.

Trilobites are found in the conglomerates at Taylor's Falls more abundantly than any other fossils with the exception of *Obollela polita*. In this case also a greater distribution is noted. Many specimens of a species of *Dicellocephalus* were found in the Franconia sandstone in a horizon at least 100 feet higher than the conglomerate strata. All but two specimens are referred to the genus *Agraulus* and are closely related as a group to *A. convexus* Whitfield, the greater number of specimens clearly belonging to that species. One of the other above-mentioned specimens is regarded as identical with *Ptychoparia* (*Conocephalites*) *calymenoides* Whitfield, while the other is so clearly distinct from any form with which I am familiar that it is described as the type of a new genus.

Genus **Agraulus**, Hawle and Corda, 1847.

The trilobites found in this conglomerate are very closely related to *A. convexus* Whitf. Many specimens are no doubt of the same species while those showing a considerable difference have been assigned new specific names. A considerable range of variation is allowed for Whitfield's species on the grounds suggested in a later paragraph. The described differences are of necessity confined to the head parts and their proportions since the other parts of the animal are poorly preserved.

In all of the forms here referred to *Agraulus* the eyes are far removed from the glabella, and the facial suture extends from the eye with a slight curve directly to the lateral margin cutting it at nearly a right angle, and posteriorly it cuts the margin just within the genal angle. The glabella is clearly defined but shows marked differences in the several groups of specimens.

Agraulus convexus Whitfield.

Arionellus (*Agraulos*) *convexus* Whitfield. Ann. Rept. Wis. Geol. Survey for 1877, p. 57, 1878.

Arionellus convexus Whitfield. Geol. of Wisconsin, vol. IV, p. 190, 1882.

Plate XX, Figs. 9, 10 and 11. Plate XXI, Figs. 3 and 7.

Cephalic shield strongly convex; glabella strongly defined by the dorsal furrows, somewhat narrower at anterior extremity and bounded by almost a straight line which curves narrowly to the dorsal furrows; three faint oblique lateral furrows on the glabella; occipital furrow deep above but disappearing at the dorsal furrows and again continued faintly across the posterior portion of the fixed cheek; fixed cheeks a little more than half as wide as the glabella, strongly arched at the eyes; frontal limb deeply cut by a median groove which marks off an anterior marginal rim, wider and more prominent in front than at the lateral margins, forming a rounded and thickened projection extending at a considerable angle beyond the general convex contour of the shield. Facial suture runs from the eyes anteriorly outward so as to cut the lateral margin at almost a right angle and posteriorly runs abruptly to the margin within the genal angle; eyes posterior to middle of glabella; length of glabella 7 mm. without ring; length of shield 12 mm.; width of glabella anterior 4½ mm.; posterior 6 mm.; width of cheek 3 mm.; frontal limb 3¾ mm. The pygidium, fig. 11, is supposed to belong to this species.

Formation and locality: Upper Dresbach, Taylor's Falls.

In addition to the form for which the above description was written there are two others which are so similar in most points except size that they are provisionally regarded as stages in the growth of this species. One (A) is larger and the other (B) smaller than the measurements given. The former is probably a senile individual and the latter an immature form.

Variety A.

Plate XX, Figs. 1 and 2. Plate XXI, Fig. 5.

Cephalic shield more flattened giving a broader aspect to the head. Markedly less convex over the eyes. Occipital furrow imperfectly marked; glabella smooth; median groove very faintly traced and the marginal rim follows the general convex contour of the rest of the shield.

Variety B.

Plate XX, Figs. 5 and 6.

Form rather small. The cephalic shield is semicircular to lunate, strongly convex, greater width than length; glabella anteriorly con-

vergent with broadly and uniformly rounded termination, strongly outlined; three pairs of lateral furrows inclining forward, anterior pair very faint, lateral pair prominent; occipital ring very prominent, the neck furrow passing laterally across fixed cheeks; fixed cheeks large, convex, continued as a margin to the glabella sloping into a deep transverse furrow separating it from a narrow cord-like marginal rim. Length of glabella 5 mm.; inner margin less than 2 mm.; marginal rim 1 mm.

Agraulus hemisphericus, n. sp.

Plate XX, Figs. 14 and 15.

Cephalic shield strongly and uniformly convex, in general outline resembling *Illænus*. Glabella very faintly outlined, elongate with slowly converging sides to a point two-thirds the distance to anterior margin where it is terminated by a faint groove parallel to the margin; surface of glabella smooth; occipital ring outlined indistinctly and continued across the fixed cheeks similarly; fixed cheeks large and conforming to the general convexity; frontal limb without groove and continues the curve of the glabella; eyes far removed a little posterior to the middle of the glabella from which the facial sutures pass anteriorly outward cutting the margin at right angles and posteriorly with a short lateral curve cutting the margin evidently within the genal angle. Length of head 15 mm.; width 21 mm.; length of glabella 10 mm. exclusive of occipital ring; anterior width 7 mm.; posterior width 9 mm.

Formation and locality: Upper Dresbach, Taylor's Falls.

Ptychoparia calymenoides (Whitfield).

Conocephalites calymenoides Whitfield, Ann. Rept. Wis. Geol. Survey for 1877, p. 52, 1878.

Conocephalites calymenoides Whitfield. Geol. Wis. vol. IV, p. 179, 1882.

Plate XX, Figs. 3 and 4. Plate XXI, Fig. 4.

A specimen agreeing accurately with that described by Whitfield has been obtained. Unfortunately the head is not preserved, and the same difficulty as Whitfield encountered is in the way of more accurate description.

Formation and locality: Dresbach, Taylor's Falls.

Genus **Cheilocephalus,** new genus.

Etymology: *cheilos*, a lip or rim, and *cephale*, head.

Description. Cephalic shield semicircular, strongly convex, about equal to one-fourth part of a spheroid; anterior (frontal limb) formed by a narrow ring projecting at a right angle beyond the general surface of the shield; glabella broad, convex, anteriorly slightly convergent and reaching to the narrow marginal rim, surface nearly smooth, with 2 pairs of scarcely perceptible furrows, marginal grooves not strongly marked; faint occipital ring (neck ring) but more strongly marked on the cheeks; fixed cheeks broad and conforming to the general spherical outline; the posterior margin developed into a spine

like projection a little removed from the glabella; eyes a little anterior to the middle and remote from the glabella; facial sutures extend from the eyes forward almost parallel to the sides of the glabella and backward with a double curve to the genal angle.

Movable cheeks unknown as are also the other parts of the form. The description is based on one specimen excellently preserved.

Cheilocephalus st. croixensis, n. sp.

Plate XVII, Fig. 1. Plate XX, Figs. 7 and 8. Plate XXI, Fig. 19.

Size of head, width 25 mm.; length 16 mm.; marginal rim; width, 1½ to 2 mm.; glabella length 15 mm.; width anterior 9 mm.; posterior 13 mm.

Formation and locality: Upper Dresbach, Taylor's Falls.

Genus **Dicellocephalus,** Owen, 1862.

A number of specimens whose affinities were doubtfully referred to either *Ptychoparia* or *Dicellocepalus* were upon a comparison of the detailed descriptions of older species finally grouped under a single species *D. misa* Hall,* 1863.

In a paragraph following the original description of this species an explanation is made by the author which throws a good deal of light upon these forms and accounts to a certain extent for the rather more than usual difficulty in identification. He says: "In species like this one, it is not easy to point out the characters which separate them from such forms as *D. spiniger* or *D. pepinensis* and we have the features of glabella intermediate between the more characteristic forms of *Conocephalites* (*Ptychoparia*) and *Dicellocephalus*. In this one the glabella is more conical and the posterior glabellar furrows scarcely united across the summit."

"The pygidium which occurs in several specimens associated with the glabella, has the prominent axis and broad lateral lobes with wide margin which are characteristic of *Dicellocephalus* and I am therefore induced to place the species under that genus."

Dicellocephalus misa Hall.

Dikelocephalus misa Hall. 16th Rep. N. Y. Mus. Nat. Hist., 1863, p. 144.

Plate XX, Figs. 12 and 13.

"Glabella prominent, somewhat conical, truncate at the apex, length about equal to width at base, which is more than one-third greater than the width in front. Three pairs of furrows are visible; the posterior ones oblique and sometimes slightly marked across the middle, leaving the posterior lobes deeply separated and directed forward at the extremities. Median lobes and furrows directed a little forward; anterior furrows faintly impressed, leaving a very narrow anterior lobe; occipital furrow well defined, straight in the middle.

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*16th Rep. N. Y. Mus. Nat. Hist., 1863, p. 144.

and curving a little upward at the sides; occipital ring wider in the middle curving forward towards the extremities."

"Facial suture directed slightly inwards from the anterior margin, and thence curving gently outwards, it follows the line of the palpebral lobe nearly to the occipital furrow, when it turns abruptly outwards. Dorsal furrows rather wide and deep, continuing rather less distinctly round the front."

"Fixed cheeks narrow, expanding in the direction of the eye, and separated from the palpebral lobe by a long distinct sigmoid groove: posterior limb narrow, its extent unknown. Frontal limb of moderate width, separated from the glabella by a narrow groove, marked along the middle by a broad shallow transverse furrow, which is stronger at the sides and sometimes nearly obsolete in the middle; anterior margin flattened, and a little produced in the middle."

Differences are chiefly in points relating to the frontal limb. The smaller specimens differ only in having a narrower frontal limb than those which are of twice the size. While those few specimens which are very large have the frontal limb anterior to the groove very much produced into a broad and prominent shovel-like projection, which adds much to the differences in comparative length of head in different specimens. The specimens vary in size from a length of 5 mm. to a length of 25 mm. for the head of the largest one found.

On account of this seemingly constant variation with the size of the specimens, it has been considered most probable, in the absence of other marked differences that all belong to the same species and that differences in size with accompanying development noted above indicate the comparative maturity of different individuals.

Formation and locality: Franconia sandstone, Franconia, Minn.

CHAPTER III. *Summary and Correlation.*

The vertical range of some of these species is shown to be much greater than before supposed.

Lingulepis pinniformis Owen, is most abundant near the base of the formation in the calcareous layers of the shales, but specimens are also found in the Taylor's Falls conglomerate indicating a vertical range of more than 125 feet. Above the Dresbach no specimens of this species have been identified in this area.

Tryblidium barabuensis (Whitfield), is identified from the Jordan sandstone while the related forms *T. convexum*, n. sp., and *T. extensum*, n. sp., are from the marginal conglomerates of the Dresbach. Therefore the range exhibited by these similar species is about 200 feet.

The species of *Agraulus* show narrow range, as do also those of *Dicellocephalus*, each being found in a single horizon.

The value of this fauna lies

1st. In its bearing upon the question of the position of these rocks in the geologic scale.

2nd. In the addition that it has made possible to the paleontology of the primitive Gastropoda.

3rd. In the morphologic series that the different species present.

4th. In the aid it has given to minor stratigraphic subdivision of these formations.

5th. In the data furnished for use in correlation.

The general aspect of this fauna is identical or at least very similar to the Baraboo fauna described by Whitfield, which he referred tentatively to the Oneota of the Magnesian series. Evidently the strata from which it was taken must belong to a lower horizon at or above the middle of the Basal Sandstone series in accord with the possibilities of structure pointed out by Irving, for no such excessive vertical range as this is found in any locality where the succession of formations is clear. But the Taylor's Falls fauna does not strengthen the claim to strata of Middle Cambrian age in Minnesota. The occurrences of species of *Euomphalus*, *Tryblidium*, *Agraulus*, *Lingulepis*, *Obolella*, *Hyalithes*, etc., all together, although combining to a certain degree characters of both the Middle and Upper Cambrian, do not as a whole present a primitive faunal aspect. So that whatever may, after more careful exploitation, prove true of those strata represented by the great lower sandstone member, it is at least probable that the strata represented by the Dresbach shales and all above it should be regarded as Upper Cambrian.

EXPLANATION OF PLATES.

PLATE XVII.

Figures about natural size.

Fig. 1. *Cheilocephalus st. croixensis*, n. sp., (type of genus). P. 290.

Fig. 2. *Hypseloconus recurvus* (Whitf.), var. *elongatus*, (type of genus). P. 284.

PLATE XVIII.

Geological map of the St. Croix Dalles. The map is intended to locate the outcrops of the different rocks in more detail and with greater accuracy in the vicinity of the village of Taylor's Falls than is possible on the map of the whole district. The map covers four square miles.

PLATE XIX.

Figures all natural size.

Figs. 1-2. *Hypseloconus* (*Metoptoma*) *recurvus* (Whitf.), var. *elongatus*, (elevation and aperture). P. 284.

Figs. 3-8. *Hypseloconus recurvus* (Whitf.) P. 284.

Figs. 9-10. *Hypseloconus cylindricus*, n. sp. P. 285.

Figs. 11-12. *Hypseloconus cornutiformis*, n. sp. P. 285.

Figs. 13-16. *Hypseloconus recurvus* (Whitf.) P. 284.

Figs. 17-18. *Hypseloconus franconiensis*, n. sp. P. 285.

Figs. 19-20. *Hypseloconus capuloides*, n. sp. P. 285.

Figs. 21-24. *Hypseloconus recurvus* (Whitf.) P. 284.

Figs. 25-26. *Hypseloconus stabilis*, n. sp. P. 286.

Figs. 27-30. *Hypseloconus recurvus* (Whitf.) P. 284.

Fig. 31. Outline of aperture of the largest fragment restored.

In each case the figure representing the elevation of a specimen is followed by a figure representing the outline of the aperture of the same individual.

PLATE XX.

Figures all natural size.

Fig. 1. *Agraulus* (*Arionellus*) *convexus* Whitf., (senile individual). P. 288.

Fig. 2. Side view of the same specimen showing diagrammatic outline. P. 288.

Fig. 3. *Ptychoparia* (*Conocephalites*) *calymenoides* Whitfield. P. 289.

Fig. 4. Side view of same specimen.

Figs. 5 and 6. *Agraulus convexus* Whitfield, (small specimen). P. 288.

Figs. 7 and 8. *Cheilocephalus st. croixensis*, n. sp. P. 290.

Fig. 9. *Agraulus convexus* Whitfield, (mature stage). P. 288.

Fig. 10. Side view of *A. convexus*, (diagram of head). P. 288.

Fig. 11. Pygidium of *A. convexus* probably. P. 288.

Figs. 12 and 13. *Dicellocephalus misa* Hall. P, 290.

Figs. 14 and 15. *Agraulus hemisphericus*, n. sp. P. 289.

Figs. 16 and 17. *Tryblidium extensum*, n. sp., (elevation and aperture). P. 281.

Figs. 18 and 19. *Tryblidium* (*Metoptoma*) *barabuensis* (Whitf.) P. 281.

Fig. 20. Fragment of a partially coiled form of unknown position. P. 287.

Figs. 21 and 22. *Tryblidium corpulentum*, n. sp. P. 281.

Fig. 23. *Euomphalus strongi* Whitf., var. *sinistrorsus*. P. 287.

Figs. 24 and 25. *Tryblidium convexum*, n. sp. P. 280.

Fig. 26. *Scævogyra minnesotensis*, n. sp. P. 286.

Figs. 27 and 28. *Tryblidium aduncum*, n. sp. P. 282.

Figs. 29 and 30. *Tryblidium rectilaterale*, n. sp. P. 280.

PLATE XXI.

Fig. 1. *Lingulepis pinniformis* Owen.
Lingulepis acuminata Con. (Walcott).
Fig. 2. *Hypseloconus* (*M.*) *recurvus* (Whitf.), var. *elongatus*. P. 284.
Fig. 3. *Agraulus convexus* Whitf. P. 286.
Fig. 4. *Ptychoparia calymenoides* (Whitf.), (and head of *A. convexus*). P. 289.
Fig. 5. *Agraulus convexus* Whitf., (senile individual). P. 288.
Fig. 6. *Hypseloconus stabilis*, n. sp. P. 286.
Fig. 7. *Agraulus convexus* Whitf., (average size). P. 288.
Fig. 8. *Hypseloconus recurvus* (Whitf.), (small). P. 284.
Fig. 9. *Euomphalus strongi* (Whitf.), var. *sinistrorsus*. P. 287.
Fig. 10. *Hypseloconus franconiensis*, n. sp. P. 285.
Figs. 11-14. *Hypseloconus recurvus* (Whitf.), (three different forms). P. 284.
Fig. 15. Fragment of a partially coiled form of undetermined affinities. P. 287.
Fig. 16. *Hypseloconus recurvus* (Whitf.), P. 284.
Fig. 17. *Tryblidium rectilaterale*, n. sp. P. 280.
Fig. 18. *Tryblidium convexum*, n. sp. P. 280.
Fig. 19. *Cheilocephalus st. croixensis*, n. sp. P. 290.
Fig. 20. Slabs showing several casts of *Hypseloconus recurvus*. P. 284.
Fig. 21. *Hypseloconus recurvus* (Whitf.), var. *elongatvs* (type). P. 284.

[European and American Glacial Geology Compared, IV.]

THE PARALLEL ROADS OF GLEN ROY.

By WARREN UPHAM, St. Paul, Minn.

In the western part of the Lochaber district of the central Scottish Highlands, from nine to twenty miles northeast of their highest mountain, Ben Nevis (4,406 feet), is Glen Roy, in which the river Roy flows southwest to the river and Glen Spean, tributary to the southern end of loch Lochy and thence by the river Lochy to the sea in loch Linnhe at Banavie and Fort William. These glens, with Glen Glaster (Glas Dhoire), opening into Glen Roy from the east, Glen Collarig, which is a lower affluent of the Roy from the west, and the upper part of Glen Gloy, lying between Glen Roy and loch Lochy, to which it is independently tributary, bear, on their inclosing hill and mountain slopes three parallel horizontal shore lines,

PLATE XIX.

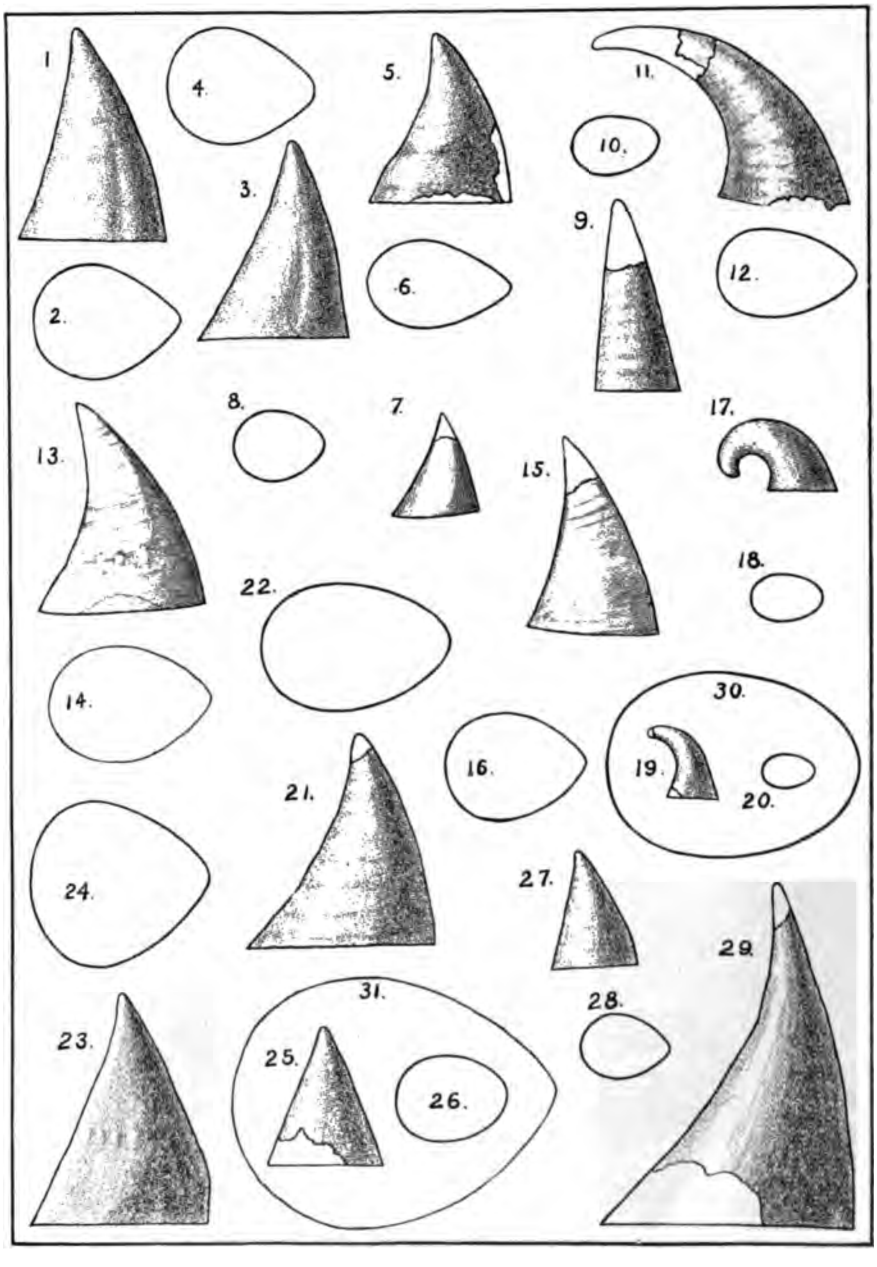
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PLATE XX.

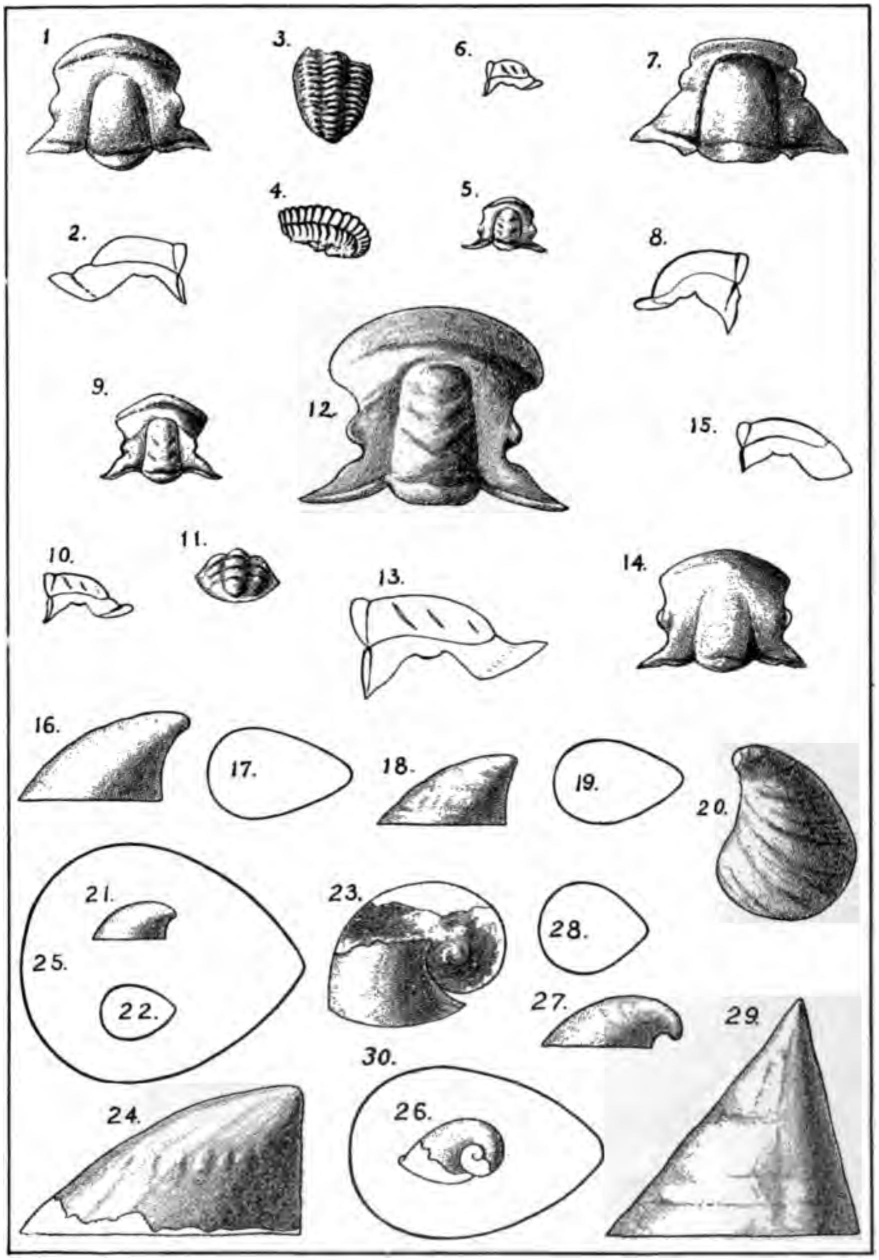
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PLATE XXI.


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(excepting that Glen Gloy and Glen Spean have each only one), which were the chief geological attraction and object of pilgrimage for me in the British Isles.

Traditionally called roads of the mythical hero Fingal and his hunting parties, these mysterious, delicately traced, level lines far up the valley sides were long ago examined by Macculloch, Dick Lauder, Milne-Home, and others, who explained them as shores of lakes once held in these narrow mountain glens by barriers of detrital matter which afterward were washed away. On the other hand, Chambers, Darwin, Nicol, and others, from their examination, thought them to be marine shore lines.

Agassiz, in 1840, visiting the district with Dean Buckland, supplied the key of the true interpretation of these shores in the suggestion that lakes were held at the levels of the Parallel Roads because the lower parts of the glens were obstructed by glaciers. This view has been elaborated by Jamieson, Prestwich, James Geikie, and others, ascribing these lakes to local glaciers of the mountain valleys, as in the case of the Merjelen See on the east side of the Great Aletsch glacier in the Alps. To my mind, however, this seems an inadequate expression, far less acceptable than the latest discussion and explanation given by Jamieson in 1892, in which the Lochaber glacial lakes are referred to the barrier of the waning and southwestwardly receding remnant of the general Scottish ice-sheet.*

The glacial lakes Roy and Gloy (as I may name them for the present description) are the earliest recognized examples of their class, which comprises many anciently ice-dammed lakes now known and partially mapped in the great valleys and basins of Scandinavia east of its mountainous watershed but west of the ice-shed during the Glacial period. In America, on a much grander scale, we have the glacial lakes Agassiz, Saskatchewan, Souris, and Minnesota, whose drainage was turned by the waning ice-sheet into the upper Mississippi river; and the complexly interrelated glacial lakes Duluth, Chicago, Saginaw, Maumee, Whittlesey, Warren, Algonquin,

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*Quart. Jour. Geol. Soc., XLVIII, 5-28. This paper has many bibliographic references to the extensive literature of the Parallel Roads, for which also consult William Jolly, in Nature, XXII, 68-70, May 20, 1880.

Lundy, Newberry, Iroquois, Hudson-Champlain, and St. Lawrence, in the compound hydrographic basin of the present great lakes tributary to the river St. Lawrence. For the United States and Canada, Chamberlin has well observed that if an attempt were made to enumerate all our glacial lakes, large and small, temporarily formed in valleys and basins sloping toward the retreating border of the ice-sheet, they would be counted "not by scores and hundreds, but by thousands."

July 1st and 2nd of last summer, two very clear and beautiful days, were given to my examination of Glens Roy, Gloy Spean, and their tributaries, and the cols over which the glacial lakes outflowed. Coming by railway from Fort William to Roy Bridge station, I thence walked up Glen Roy, and up the Turret and Chomhlain valleys, its northwestern tributaries, to the Gloy col; slept in a shepherd's cottage; walked back to Glen Glaster, over its col to the Spean, onward to loch Treig, and back to Tulloch,(formerly Inverlair) station; and thence returned by railway to Fort William. Excepting the westward and late extension of lake Roy down the Spean valley below the junction of Glen Roy, all the district thus observed lies on the Glen Roy sheet (63) of the Ordnance Survey of Scotland, which has the scale of a mile to an inch and is contoured for each 250 feet of altitude. This sheet, in accordance with the request of Milne-Home, includes detailed mapping of the Parallel Roads.

Lake Roy began with outflow northeastward from the head of Glen Roy into the river Spey, whose valley was earlier uncovered from the receding ice-sheet. The col between the Roy and Spey is 1,151 feet above the sea, this being the surface of a shallow peaty swamp, which, filled a few feet above the old river bed of outflow, occupies the water divide in the continuous, mountain-walled valley. Along the distance of about a mile thence to loch Spey the pass has a descent of only nine feet. The highest wave-worn shore of lake Roy, recording its extension while outflowing at this col, has an altitude of 1,150 feet, very nearly, the upper and lower limits of the perceptible wave erosion being, according to the Ordnance Survey, at 1,155 and 1,144 feet. The lake at this level attained, with the recession of the ice-sheet, a length of nine or ten miles, to the north side of Bohuntine hill and Glen Glaster,

where the highest shore terminates. The maximum depth of the lake in this stage, east of Bohuntine hill, was 650 feet. Its width in the Glen Roy was mainly between a half and three-fourths of a mile, and it was only slightly diminished in width along this mountain valley by sinking to the later and lower shores.

When the ice-sheet, in its general southwestward recession from this mountainous region, laid bare the col at the head of Glen Glaster, leading into the Spean valley, lake Roy was lowered to that pass. For a short time, perhaps a few years, this new outflow was stationary at a level of about 1,100 feet, shown by a faint shore mark seen along a distance of about two-thirds of a mile where the Roy valley bends northeast of the Turret bridge. Winds blowing through the valley had a longer stretch of the lake for raising its waves there than on any other part of its shores. Elsewhere this beach line is wanting or scarcely observable.

The Glaster col has an altitude of 1,075 feet, being filled up with peat several feet above its original hight. Its belt of shore erosion, constituting the middle one of the Parallel Roads, lies between upper and lower limits of 1,077 and 1,062 feet. The lake surface was nearly at 1,070 feet, with wave wearing in storms above and beneath that level. The earliest outflow in the Glaster pass may have been upon its northeast side about 30 feet above the central depression which was soon afterward occupied when permitted by slightly farther retreat of the ice. Or a barrier of glacial drift about 30 feet high may at first have obstructed the valley close southeast of the later col, where now such drift deposits partly remain, facing the brooklet with steeply undercut front.

During the formation of the Glaster shore line the lake extended about a mile farther down Glen Roy, and into Glen Collarig over the pass north of Bohuntine hill, than at its earlier highest stage. Its maximum depth, at the lowest point to which it extended, was nearly the same as before.

With the recession of the ice-sheet only one mile and a half southward from Glen Glaster, around the west side of Creag Dhubh, lake Roy spread into the Spean valley and fell about 215 feet more, to the level of the col east of loch Laggan, between the Spean and Spey valleys. This col has a

hight of 848 feet, being now cut probably several feet below its level during the existence of the glacial lake. Shore erosion making the lowest Parallel Road during this time of latest and greatest extension of lake Roy was limited between 862 and 850 feet. The lake held nearly the level of 855 feet, being 36 feet above loch Laggan, and having a maximum depth of about 550 feet at its most southwestern part, in the Spean valley about two miles below Roy Bridge. The length of lake Roy in its latest stage, while outflowing beyond loch Laggan, exceeded twenty miles in the Spean valley with a width of about a half mile easterly and nearly two miles at the west. It reached up Glen Roy about ten miles, terminating three miles below its col.

The three principal Parallel Roads, approximately at 1,150 feet, 1,170 feet, and 855 feet above the sea, which were the shores of lake Roy in its stages of these different outlets, are of nearly equal development. They are very narrow beaches cut by the waves in the now grassy and heathery drift which thinly overspreads the rocky mountain sides, and are best seen from some considerable distance by the eye following their level lines of brighter green than the general slopes. Prof. Henry D. Rogers, after his visit to Glen Roy nearly forty years ago, wrote of its Roads: "Seen in profile, as when looked at horizontally, they resemble so many artificial hill-side cuttings, the back of each terrace lying within the general profile of the mountain slope, while the front or outer edge is protuberant beyond it." Jamieson says: "Each of the Parallel Roads consists of a sort of terrace or shelf, generally from 40 to 70 feet broad, and sloping towards the middle of the glen at angles varying from 5° to 30°."

The best point for obtaining an extensive and impressive view of these shore lines from the Glen Roy highway is on the small marginal moraine east of Bohuntine hill, looking thence up the glen. Good photographs of this view are for sale at Fort William. Much depends on having favorable light and clear air for seeing these delicate shore marks most satisfactorily. Their small, though very well defined development, when compared with the shore erosion and beach deposits of the glacial lake Agassiz and with the modern great lakes of the St. Lawrence, seems to me to betoken only a short duration

of lake Roy, perhaps no more than one or two centuries for all its stages together. About a third part of its whole time of existence, represented by the formation of the Glaster shore line, elapsed during a retreat of the ice border across a distance of less than two miles.

Lake Gloy, which attained a length of about six miles, with a width of one-fourth to three-fourths of a mile and a maximum depth of about 700 feet, overflowed from Glen Gloy into the Chomhlain and Turret arm of Glen Roy. The col is 1,172 feet above the sea, but it is filled up about six feet with peat. The Gloy shore erosion lies between vertical limits of 1,173 and 1,156 feet, the surface of the lake having been at 1,166 feet, very nearly. Its single shore line is, I think, more conspicuous than either of the Glen Roy Roads. The outflowing stream, during the highest stage of lake Roy, had a descent of about 16 feet and a length of perhaps a third of a mile

Both these glacial lakes were brought to an end by the southwestward retreat of the ice, when it opened the Gloy and Spean valleys to the area of loch Lochy in the Great Glen of Scotland. Although that deeper and broader, nearly straight glen or valley was still filled by the fast waning ice-sheet on the southwest, it was wholly open northeastward past loch Ness to the sea. Its present watershed has an altitude only slightly exceeding 100 feet, across which the ice-held lakes of the Gloy, Roy, and Spean valleys were plainly drained away.

Excellent opportunity to trace the old shore lines is afforded by the absence of trees or even bushes from nearly all the country. But in many places the stumps and roots of trees were observed in the peaty soil, where any rivulet had cut to a slight depth. The destruction of the former groves and woods here seems probably attributable to their use for fuel, as in some almost entirely prairie areas of the upper Mississippi basin.

Deltas of very small volume were brought into lake Roy in its successive stages by several of its tributaries. All these streams are short, and they had only a brief time for this work during the existence of the glacial lake. Their later alluvium carried into the glen is of far greater volume, as notably in

two admirable alluvial fans sloping down on the east side of the glen at one and two miles below the mouth of the river Turret. The massive drift accumulations which the Turret intersects near its mouth, regarded by Jamieson as a delta, seem to me better interpreted by Prestwich as a marginal moraine of the ice barrier when it stood there, four and a half miles west-southwest of the Roy-Spey col.

The next paper in this series will describe the many recessional moraines seen between the head of Glen Roy and Ben Nevis, and will present reasons (following Jamieson) for regarding the retreating Scottish ice-sheet as the barrier of the lake which formed the Parallel Roads.

TERTIARY AND QUATERNARY DEPOSITS IN THE MAGELLAN TERRITORIES.

By Otto Nordenskjold, Upsala, Sweden,

During the two Antarctic summers, 1895-96 and 1896-97, that I spent in the Magellan territories (in Terra del Fuego and South Patagonia south of the Santa Cruz river) I concentrated my attention largely upon studying the most recent deposits of those regions with especial regard to the possibility of being able to trace any proof in them of a glacial period. It is of the results of those researches in so far as they are already to hand that this paper is intended to give a short account.

Seeing in the first place that the general character of the Tertiary deposits in South Patagonia has been the subject of a number of recent papers embodying results of researches,* and in the second place that the parts of the district I visited are some of the poorest in the matter of fossils, I

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*The principal works treating of these deposits, and which will be drawn upon for quotations below, are:

A. Mercerat. Essai de classification des terr. sediment. de la Patagonie australe. Ann. Mus. Buenos Aires, V, 105.

F. Ameghino. Geology of Argentina, Geol. Mag., Jan. 1897.

J. B. Hatcher. Geology of Southern Patagonia, Am. Jour. Sci., Nov. 1897.

Of great importance for these questions are also

Chas. Darwin. Geological observations in South America, London, 1876.

L. Agassiz. South American expedition, Nature, 1872, VI, 216.

was constrained to lay chief stress in my labors upon such researches as should serve to establish the physical, in especial the climatic, conditions during the period in question, and upon collecting plant fossils that in many places occur in strata belonging to the middle sections of the Tertiary formation, viz: the Supra Patagonian and the Santa Cruz beds.

Leaves belonging to the species of the genus Fragus are the commonest finds; among them the most useful, probably, is F. magelhænica, described by Engelhardt as found in Punta Arenas. This proves that the vegetation at that period had the same character as at present. That the climate, however, must have been somewhat warmer seems proved by a find that Nathorst has made among the collections we brought home, viz: a broad-leaved species of Araucaria (group Colymbea) in Tertiary clay from Punta Arenas. That the climate, however, must have been damper seems to be evident from the fact that strata of coal and remains of a luxuriant vegetation have been come upon in localities where to-day no arboreal vegetation occurs. Engelhardt, however, describes* a portion of a palm leaf found in the place just referred to, and comes to the conclusion that the climate at that time must at least have been subtropical. That is, nevertheless, not plausible, unless confusion of locality exists, the leaf probably coming from some quite different deposit older than that containing Fragus and Araucaria.

The most recent deposits in Patagonia that contain fossils, so far as hitherto known, are the Cape Fairweather beds, described by Hatcher. He collected from them specimens of a mollusk-fauna somewhat poor in the matter of species and submitted the same to Pilsbry for him to describe. The description he gives shows that the strata cannot be older than Pliocene. They gradually yield place to the Patagonian boulder formation above, the age of the latter being thereby fixed at their earliest limit.

Relying on Darwin's description, Hatcher correlates the Cape Fairweather beds with the Tertiary deposits at San Sebastian bay in Terra del Fuego. From that place and its vicinity I have brought home a large number of fossil plants and mollusks. The latter have been consigned to the charge of Prof.

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*Abh. Senckenb. Naturf., Ses. XVI, 629.

Steinmann for description. He writes that on a hurried examination he finds that they do not seem to bear any great resemblance to the fauna Pilsbry treats of, but that he is not prepared at present to give any opinion as to the age of the strata.

In the most recent Tertiary strata in Terra del Fuego veins of lignitic coal and vegetable remains are found in many places, and one might assume that we had a fresh-water formation here, corresponding to the Santa Cruz beds in Patagonia. In a specimen of a clay, however, from the Cullen river, deposited immediately beneath and in contact with glacial gravel, the clay being in other respects free from fossils, Cleve has discovered remains of a tolerably rich marine flora of Diatomaceæ; hence, it seems most probable that this clay is an analogue of the Cape Fairweather beds.

The Tehuelche, or boulder formation mentioned above, is not only the most peculiar of the deposits in Patagonia, but it is also the one about the mode of whose origin the greatest diversity of opinion has prevailed. The deposit is as much as sixty metres thick, and plainly consists of stratified shingle and gravel, sometimes mixed with sand. As the result of investigations made by Darwin, Doering, Sieniradzki, Ameghino and others, it has been supposed that this deposit extended uniformly over the whole of Patagonia—high plateaus and lowlands alike—up to the Colorado river. The majority of the investigators who have considered the question have held the deposit to be marine; some, and Steinmann among them, have connected it with the glacial period of these regions, without, however, as a rule, expressing any opinion as to the mode of its formation. Hatcher embraces the former hypothesis by reason of the above-mentioned fact that the shingle formation passes into the Cape Fairweather beds below. As now formations similar to these beds would not at present seem to have been come upon anywhere but at a hight of from 100 to 150 metres above the present sea-level, and in the immediate vicinity of the shore, the observation made does not afford reasons enough to assume, for so late a period, such an immense depression of the land, of necessity nearly 1,000 m. at least. If this were so it would be strange

not to find any deep-sea formation on the lowlands, analogous to the conglomerates on the shore.*

This fact has no further bearing upon the question of whether the shingle formation is to be connected with a glacial period. On the other hand, the probability of that being the case has been considerably strengthened by the discovery I made in Terra del Fuego of immense masses of gravel of an exactly similar character existing in immediate proximity to the glacial boulder-clay described below. Moreover, in Western Patagonia, in the district watered by the upper reaches of the Coile river, I found intercalations in the shingle formation of undoubted glacial origin.

The supposition that commends itself most strongly to me is that the shingle is formed by big rivers whose sources were immense glaciers and which flowed through country with a comparatively level surface, and hence, by reason also of the vast deposits, often altered their courses. This view of the case is the same as that propounded by von Haast as an explanation of the strata occurring in the Canterbury plains, New Zealand.† To appreciate the feasibility of this explanation, one must call to mind the fact that all data concerning the thickness of the gravel comes from the present-day river-valleys. It is only there that sections in the gravel are to be found. It is not even possible to establish whether this gravel occurs over the whole of the plain, since there it is often covered over with later sedimentary deposits—"loess"—with intercalations of sand and gravel. If we now assume that the rivers of to-day have for the most part the same courses that their mighty predecessors in glacial ages followed, we should arrive at an explanation of the circumstance that the gravel exists to such a great depth in the walls of the present river valleys.

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*The statement made by Ameghino that intercalations have been met with in the bowlder clay, containing the shell of an Ostrea "of the same type as the Ostrea bourgeoisi," is very interesting, but is at the same time so incomplete that no conclusions can be drawn from it. Since the inquiries prosecuted by Hatcher it does not in any case seem likely that it can have any bearing on the question of the age of the formation.

†J. von Haast. The Geology of Canterbury and Westland, 1879.

‡Furthermore also because if we assume two separate glacial periods, part of the gravel (to be) found in Patagonia probably belongs to the formations in the second period.

This formation, both in appearance and in locality, very strongly reminds one of the nagel-flue formation that distinguishes the first descent of the ice in the Alps, and it would seem highly probable that the mode of origin in Patagonia is the same, though there the phenomenon has been of much greater extent.

The boulder formation is most extensive in Central Patagonia; in the southernmost part of the continent and in Terra del Fuego it is of much less importance. In those parts it is replaced by another not less interesting formation that can be very conveniently investigated at many points on the east coast of Terra del Fuego, for instance at cape San Sebastian. The "barranca," over sixty metres in hight, consists throughout of an entirely unstratified clay containing, in the utmost disorder, masses of angular-shaped stones varying in size from the smallest imaginable to great blocks of a volume of several cubic metres. Among these stones there are many that display traces of glacial polish and stria. Fossils are not found* with the exception of occasional broken shells of a Turritella, common in the underlying Tertiary deposits; these are presumably not original here. It cannot be questioned that this boulder clay is formed in the same manner as the corresponding deposits in the northern hemisphere, and that it constitutes the ground moraine of a thick layer of land-ice.†

On the coast further north numerous irregular, often lenticular intercalations of gravel and sand occur. These do not contain either any traces of fossil remains. They are noticeable, however, for a cross-bedding, extremely usual and plainly to be seen. This is characteristic of river-glacial deposits, and the sand is frequently permeated with small faults. Both above and below the boulder clay irregular layers of sand and gravel are often found. Still further north the boulder clay itself forms an intercalation in a thick shingle formation on the plateau; it often takes the form of two or more narrow somewhat irregular layers, one above the other.

This boulder-clay gives origin to a peculiar form of land-

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*Not even Diatomaceæ or other microscopic organisms.

†Of the blocks the majority consist of rock varieties from the Cordilleras; of these many have proved under the microscope to be identical with the white granite from the Western islands.

scape, with numerous low, rounded hillocks, in which small mounds abound, on either side of the two huge valleys that here intersect the country, viz: Magellan straits and the San Sebastian valley. On the high ground between these two valleys and on the hights to the north and south, the boulder clay is only met with up to a certain elevation. The loftiest of the high plateaus in Patagonia and Terra del Fuego alike are covered with shingle.

In the eastern parts of Patagonia the ground moraine has only been met with in typical form in the vicinity of the Magellan straits. Near the foot of the Cordilleras typical districts are here and there to be found—for instance, north of lake Sarmiento,* consisting of irregular but extensive terminal moraines covered at intervals with rocks. In other places the moraine formation is replaced by another, for instance in the extensive lowland that stretches east of Disappointment bay and then continues northwards to expand again at the south base of the Bagnales mountains.

The ground throughout this district consists of sandy clay, more or less plentifully supplied with stones that are often edged and occasionally scratched. It almost always displays a clearly marked stratification and occasionally gives place to strata of typical sedimentary clay. None of these formations contain either macroscopic or microscopic organisms—in itself a strong reason for assuming glacial origin. They have undoubtedly, however, been formed under water, but in close enough proximity to the edge of the ice to allow quantities of stones brought down by floating ice to be embedded contemporaneously with the silt. Whether the deposition took place in the sea or in inland lakes in the absence of organisms has not been able to be established. If the former was the case the sea must have been at least 100 to 150 metres higher in the glacial period than now.

Reliable proof of land elevation at a late date is also forthcoming in other parts; the elevation is not, however, so great as has hitherto been supposed. On the south side of Useless bay at the hight of fifty-five metres there is a terrace constituted of a former beach; numerous large blocks of white

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*Cf. the sketch-map published in the Geographical Journal for October, 1897.

granite rest on it. Hence this beach, too, is to be attributed to the glacial period. At about the same elevation, between fifty and seventy metres, similar terrace lines are to be found at many places in the archipelago, pointing to a higher water mark in earlier times.

Below this mark there are to be found in many parts of the valleys stratified formations usually of clay. These are vary scarce in fossils, though they have on examination been proved to contain marine Diatomaceæ and sponge spicules.

A remarkable feature of the whole district is the immense size and development of the valleys. In relation to the rivers flowing through them, these valleys are mostly broad, with lofty and steep though not perpendicular walls. Down below, through a quite level country, the river slowly makes its way in complex snake-like meanderings. This state of things recurs in the mountain district of the Cordilleras and in the Quaternary and Tertiary elevated plains of the Pampas.

To now pass the development of the Magellan Territories during the most recent geological phases in review:

During the Santa Cruz period that, according to recent inquiries corresponds approximately with the Miocene period in the north, a wide continent already existed here, probably forming a low, marshy country with numerous fresh-water lagoons on its surface. The country was overgrown with extensive forests, at that time as at the present principally species of the beech, but also with Araucaria and other varieties. These forests were the abode of strange beasts, Homunculus, Xylotherium, Typotherium, Macrauchenia and many others. The climate was warmer and more humid than at present, though by no means tropical.

Thereupon, came in the Pliocene period a depression; the present coast territories, at any rate, were below water, in which at that time the fauna of the Cape Fairweather dwelt, forms, of which some still exist in those regions, while others, for instance certain large varieties of Ostrea, are extinct.

It is possible that contemporaneously an elevation took place in the west, for otherwise it is difficult to explain the phenomenon that thereupon ensued. Enormous quantities of ice collected in the Cordilleras; they did not, it is true, stretch far across the plain to the east, but they brought down, in the

rivers that arose when they began to melt, great quantities of gravel and boulders right to the shore of the sea.

Thereupon succeeded an intervening space. Whether we are to suppose it only a temporary retreat on the part of the ice or if it was really an inter-glacial period cannot be determined, since there are no fossiliferous deposits known left by it. The intimate connection that seems to exist between deposits belonging to the first and those belonging to the second glacial period argues in favour of the former supposition. In any case the between-period was of considerable duration, for the majority of the great valleys of the district arose by the process of erosion while it was in progress. Thus the most important of those valleys, the Magellan straits (eastern section) and the San Sebastian valley, date from this period, possibly also Gallegos valley. At the same time the great lowland districts, now partially covered with water, were formed; they extend from the eastern base of the Cordilleras and now constitute: Broad Reach (a section of the Magellan straits), Disappointment bay, the plain that lies south of Bagnal mountains, etc. The moraines and other deposits of the first glacial period, that undoubtedly were to be found here previously, were thereby destroyed.

Once more the ice advanced. It is probable that the blocks of ice were vaster than before; at the same time it was now more possible for it to extend over the broad newly formed valleys. The southernmost of these, the San Sebastian valley, was occupied by a gigantic "mer de glace," that along with its outlying névé-fields had an area of 20,000 square kilometres at least, and probably was joined to the almost equally extensive glacier that existed in the eastern section of the present Magellan straits. Further north no such glaciers have been discovered. In their place on the great lowland, east of the Cordilleras, between 50° 50′ and about 52° south latitude, a body of water containing drift-ice extended, probably a lake dammed up with ice, or possibly an arm of the sea.

It is established that the sea, at a time when it was full of floating ice-bergs, stood at least sixty metres higher than at present. That time, however, need not necessarily be so very far removed from the present. Many reasons, indeed,

seem to point to the glacial period having lasted down in these regions to. from a geological point of view, quite a recent date, one of the most telling being the great poverty in both the fauna and flora in Terra del Fuego in comparison with Patagonia. It is difficult to explain why quantities of mammals, reptiles, insects, phancrogamous plants, etc., that still survive on the north shore of the Magellan straits, that are only three kilometres in width, are non-existent in Terra del Fuego and are represented by other varieties, unless we assume that outward circumstances, presumably a cold climate, prevented their coming hither until recent times.

Thus, so far as at present known, the development in a geological sense of the Magellan territories proves to present a remarkable parallel to that of lands in the same relative latitude in the northern hemisphere. It is not less evident that in many respects the state of the case is the same here as it is in New Zealand, even though we are not yet in a position to draw anything like a complete comparison between the two portions of the globe. It is not possible for me in this short paper to bring forward a complete theory in explanation of these striking analogies between regions so far apart. It is a known circumstance that the climate in the northern hemisphere during the central part of the Tertiary epoch was warmer than now, though the ratio was not everywhere the same, and the same would seem to hold good for the southern hemisphere also. Towards the close of the same period a general deterioration in the climate ensued in all the lands round the two poles known to man, and in Europe, North and South America, in New Zealand, and in numerous hill districts. The result was the formation of vast masses of ice. How far this can have come about contemporaneously in all parts it would be difficult to determine. But even if it was only approximately at the same time in the various regions, yet all views of the matter that would explain these phenomena as purely local must appear highly improbable, and the same may be said of the hypothesis set forth by Croll that premises that the glacial periods alternated in the north and south hemispheres with, in geological computation, but short intervals between, furthermore the theory about the change of position in the earth's axis, in case we regard these variations

as regular in their reappearance. For if we know that glacial periods have occurred in so many parts of the world's surface, far distant from each other within one and the same, from a geological standpoint, short epoch, all the three hypotheses mentioned, that concern themselves with forces that must always have acted throughout the whole of the geological periods, to be probable premise that a number of cold periods must have existed even during the preceding and considerably more prolonged period of the Tertiary epoch. Since now no manifest traces of that have been come upon in any region the most plausible view is one that endeavors to explain the glacial period as being due to some temporary cosmic phenomenon that exercised its influence uniformly over the whole earth. That phenomenon had not strength enough to subinduce a covering of ice throughout the polar lands; for East Siberia had none. On the other hand it is open to doubt whether it occurred suddenly and lasted but a short time comparatively, and whether it thus caused a simultaneous glaciation in all districts where it was by reason of the conditions of temperature and humidity possible to do so, or whether, as is more likely, its effects were only gradual but prolonged, possibly through the whole of the Pliocene and Pleistocene periods, but that it was too ineffectual to cause a genuine glacial period, save in places where favourable local circumstances were at hand to promote it. In this connection it is not impossible that the facts, upon which the Croll hypothesis builds, may have a considerable importance.

What that cosmic phenomenon can have been we at present do not know. I cannot, however, refrain from mentioning, as one of the most plausible views hitherto put forth, that of Arrhenius* and Högbom, viz: that the cold climate during the glacial period was caused by a lowering of the percentage of carbon anhydride in the air, while the warm climate during the earlier part of the Tertiary period was due to a corresponding increase of the same.†

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*S. Arrhenius, Phil. Mag., S. 5, vol. XLI (1896) 1., 237. Cf. also T. C. Chamberlin, Journal of Geology, V, 653.

† A more complete discussion of the geology of the Magellan territories is to appear in "Wissenschaftliche, Beobachtungen während der Schwed. Expedition nach den Magellanländem," now in the press.

CHAMPLAIN SUBMERGENCE IN THE NARRAGANSETT BAY REGION.

By Myron L. Fuller, Boston, Mass.

The object of this paper is to show the improbability of certain assumptions which have been made as to the relative hights of land and sea during the deposition of some of the sand-plains of the Narragansett bay region of Rhode Island at the time of the final retreat of the ice sheet.

The considerable elevation of the higher terraces of the Connecticut, Thames and other rivers of southern New England above the level of their present flood-plains was at first tacitly accepted as pointing to a corresponding Champlain depression of the region below the present level. Dana. however, forcibly opposed the acceptance of such evidence as giving any absolute indication of the amount of depression. He argued that the high waters of the river valleys were due, in a large measure, not to the depression of the land, but to the enormous floods of water set free by the rapid ablation accompanying the final retreat of the ice sheet when, as he has put it*, "centuries of precipitated moisture were let loose at once." The excessive amounts of water, in connection with the natural obstacles in the shape of abrupt bends, constricted valleys, junction with large tributaries, etc., which are common to all the rivers of southern New England, is sufficient, few will deny, to account in an important degree for the great differences in the altitudes of the Champlain and the present flood plains. Ice dams, as urged by the author quoted, may also have been an efficient adjunct to the natural obstacles just mentioned. The fact that even at the present day at Hartford, some fifty miles above the mouth of the Connecticut river, the difference between high and low water has often exceeded twenty-five feet, lends considerable weight to the assumption.

In recent years Mr. J. B. Woodworth, in connection with the work of the United States Geological Survey, has made a careful study of the modified drift phenomena of the region of Narragansett bay, and has published† a description and map of the various sand-plains marking the different stages

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*Am. Jour. Sci., 3. vol. X, p. 437.

†Amer. Geol., vol. XVIII, pp. 150-168, 391-392.

of the ice retreat in that vicinity. He found that the hights of the sand-plains indicated water standing at levels varying from twenty up to 150 feet above the present sea level. The level of the higher of these sand-plains, as for example, those of the Wickford stage, "is obviously determined by local topographical conditions."* In the case of the plains of the Greenwich Cove and Barrington stages, where there is evidence of the deposition of delta-like sand-plains "with the water as high as 50 feet above the present sea level,"† the topographical conditions afford no explanation.

The periods of high water during the deposition of these plains seem to have been followed, in each case, by a fall of 50 feet or more at their completion. If ice remnants had remained in the passages of the lower bay, as Mr. Woodworth suggested‡ in his earlier paper on the retreat of the ice sheet in the Narragansett bay region, the deposition might readily be conceived as taking place in the temporary lakes formed by such obstructions. In his later paper, however, he admits that "ice dams in Glacial Narragansett bay appear incapable of affording an explanation,"§ and concludes that the changes of level "are analogous to those of our large inland rivers, and come under the head of flood changes," thus agreeing with the views set forth‖ by Dana in regard to the upper limit of river border formations; namely, as already indicated, that the hights of the waters had no direct relation to that of the ocean, but were determined by the enormity of the floods aided, possibly, as suggested by Woodworth, by the "gorging" action of floating ice in the lower bay.

The difficulty of accounting for the pitch of the upper surface of the waters of the glacial bay under this hypothesis was appreciated by Mr. Woodworth, but the full extent of the requirements demanded by the postulated flood was evidently not realized. In the opinion of the writer, the explanation offered cannot be maintained. The causes so efficient when acting in the comparatively narrow valleys of our

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*Loc. cit., p. 154.

†Loc. cit., p. 391.

‡Loc. cit., p. 168.

§Loc. cit., p. 392.

‖Man. Geol. 3rd Ed., p. 551.

New England streams appear to be adequate to account for but a small part of the fifty feet which needs must be explained in the broad and comparatively open Narragansett bay. It is a noticeable fact in this connection that even at Providence, on the narrow northern extension of the bay, the level of the water is unaffected by the highest spring floods,* forming in this respect a marked contrast with the Connecticut, Housatonic and Thames rivers.

EVIDENCES.

General Reasoning.—Evidences of a Champlain subsidence in the shape of elevated shore-lines and of fossiliferous deposits are found in a fairly continuous chain surrounding New England. The subsidence was least in the south, the evidences of the raised beaches along Long Island sound and eastward indicating, according to Dana, a submergence amounting only to some fifteen or twenty feet. On the coast of Maine, as indicated by elevated shore lines and fossils, the depression varied from 230 feet to nearly 300 feet, the greater being to the north and east. At Montreal, as shown by Dawson, the depression amounted to from 500 to 600 feet.

On the west, along the valleys of the Hudson river and lake Champlain, the submergence, according to F. J. H. Merrill, amounted to 335 feet at Albany, 370 feet at the southern end of lake Champlain and to 500 feet at St. Albans (Baldwin). That the interior of New England partook of the same movement of subsidence is shown by the high river terraces everywhere abounding, and indicating, even after due allowance has been made for the flooded condition of the rivers at that time, an altitude much below that at present existing.

Montreal is almost exactly 300 miles north of Long Island sound, hence the average increase in the amount of the submergence to the north was 1 2-3 feet per mile. If, as urged by Dana,† the submergence along the coast at the mouth of Narragansett bay was fifteen feet, then the hight of the water at Providence, twenty-eight miles distant, should have been forty-seven feet above this level, or sixty-two feet above the

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*Am., Jour. Sci., 3, vol. X, p. 435.

†Loc. cit., p. 434.

present sea level. It should be noticed that these figures represent a minimum subsidence, being based on the figures given by Dana—the foremost advocate of a slight Champlain subsidence in southern New England. Even this amount, however, could be made to meet, to a considerable extent, the requirements demanded by the sand-plains described by Woodworth.

Competency of Outlets.—The level of the ocean at the time of the deposition of the sand-plains being, as held by Woodworth, approximately as at present, an increase in the hight of the waters of the upper part of the bay could only take place when the capacity of the outlets to the ocean was less than the capacity of the combined glacial streams entering at the same time. It is my object to show that, in all probability, there were no floods of sufficient magnitude to cause more than a very slight rise, and certainly none sufficient to account for the rise of fifty feet demanded.

On Mr. Woodworth's map of the glacial deposits in the vicinity of Narragansett bay he gives, in addition to the higher plains laid down in water held up by local topographic conditions, eight plains with crests from forty to sixty feet elevation above tide. They are distributed from the vicinity of Wickford Junction on the south to Barrington on the north. In most of these plains the evidence as to the nature and size of the streams by which they were laid down is unsatisfactory, but the Barrington plain, which is one of the largest, has been shown to have been deposited by a single stream having a width, as indicated by its esker, not exceeding 150 feet. Our knowledge of the size of glacial streams in Alaska and Greenland leads to the belief that the depth of the water in such a stream could not have exceeded twenty feet. In order not to under-rate the importance of the stream, however, I have, in calculating the area of its cross section, assumed that it had a width, not of 150 feet, but of 200 feet, and a depth, not of twenty feet, but of fifty feet. The area of the cross section of such a stream, it will be seen, is 10,000 square feet.

There are three outlets to the sea from the upper Narragansett bay, one on each side of the Conanicut island, and a third between Aquidneck, or Rhode Island, and the main-

land. This latter is to be regarded rather as an outlet of the valley of the Taunton river and Mt. Hope bay than of the main portion of Narragansett bay, with which it is, in fact, only indirectly connected. It is, therefore, set aside as having little or no bearing upon the level of the waters of the bay.

The outlet to the west of Conanicut island, known as the Western passage, will first receive attention. According to chart No. 353 of the United States Coast and Geodetic Survey, the passage is narrowest when opposite Fox hill, having there a width of almost exactly a mile. The present average depth computed from the same source is thirty-six feet. The area of its cross section is, therefore, 190,000 square feet, or nineteen times as great as that of the glacial stream which laid down the Barrington plain. In other words, the Western passage alone could carry off the floods of nineteen such streams without appreciable increase in the hight of its waters. Considering that of the eight plains mentioned, not more than three at the most can be correlated as belonging to the same stage of ice retreat, there certainly seems no cause here for any increase in the hight of the waters.

If this is true of the Western passage, it is even more so of the Eastern passage. Referring again to the chart, we find the narrowest point of this latter passage is along a line running southeast from fort Dumpling, the width being 3,300 feet and the average depth 120 feet. The area of the cross section is, therefore, some 400,000 square feet, or forty times as great as that of the glacial stream mentioned. Both outlets remaining open, an increase in the hight of the waters could only take place when sixty or more streams of the size of the one laying down the Barrington esker entered the bay at one time. There is certainly little evidence that such was the case.

It may be argued, however, that many of the glacial streams entering the bay are unrepresented by sand plains. Granting this to be so, it is yet possible to show that with the increased surface slope of the flood consequent upon any increase in the hight of its waters, the discharge would rapidly assume proportions exceeding all possibility of supply.

Enormity of Flood Demanded.—The distance from Greenwich cove to the open sea at the southern end of Conanicut

island is fifteen miles. The plain in the vicinity of the cove indicates water standing at least fifty feet above the present sea level. It follows, therefore, that the average surface slope of the assumed torrent would have been at least three and a third feet per mile. Taking this as a basis, the velocity and discharge of the two principal outlets of Narragansett bay were computed according to the formula given by Humphreys and Abbot.* The widths and depths of the outlets in their flooded condition were calculated from the soundings and contours of the chart before mentioned. The results obtained were as follows:

EASTERN PASSAGE.

W = width = 11,500 ft. A = area of cross section = 958,400 sq. ft.

p = wetted perimeter $= W \times 1.015 = 11,672$

s = sin of slope $= \frac{h}{l} = \frac{3.33}{5280} = .0006313$

r = hydraulic mean radius $= \frac{A}{p + W} = 41.36$

v = velocity. $D = Av$ = discharge.

$$v = \left([225\, r]^{\frac{1}{4}} - s\,\tfrac{1}{2}\,.0388 \right)^2 = 13.95$$

D (approx.) $= 13,370,000$

WESTERN PASSAGE.

$W = 9,600$ $A = 388,800$ $p = 9,744$

$s = .0006313$ $r = 20.11$ $v = 9.574$

D (approx.) $= 3,722,000$

Combined discharge = 17,092,000 cubic feet per second.

The combined discharge, as has been seen, would have reached the enormous figure of over 17,000,000 cubic feet per second, or nearly twenty-eight times the discharge of the Mississippi river, and equivalent to 280 glacial streams of the size mentioned.†

Great as this flood appears, however, it is considerably less than would actually have been the case if the Champlain waters stood at a hight of fifty feet above the present level in the vicinity of Greenwich cove. The discharge at any point on the bay below this cove (which marks the probable

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*Report upon the Physics and Hydraulics of the Mississippi River, (Professional Papers of the Corps of Topographical Engineers, U. S. Army). Edition of 1878.

†The velocity of the glacial stream as indicated by its pebbles, is taken as six feet per second.

southern limit of tributary streams of any importance) would necessarily have been the same. It follows, therefore, that in the constricted outlets a considerably greater velocity, and consequently a greater slope, would have existed.

In calculating the velocity and discharge from this standpoint, the portion of the bay south of Greenwich cove was divided into two sections; the northernmost, some seven miles long, comprising the open reaches of the bay lying between Greenwich cove and the northern end of Conanicut island; and the southernmost, about eight miles long, comprising the Eastern and Western passages. The data, together with the calculated velocities and discharge, are given below:

UPPER BAY.

W = 35.000 A = 1,746,850. p = 70,525.
s = 35 in. = .0005524 r = 24.77 v = 11.18
Discharge (approx.) = 19,525.000.

EASTERN PASSAGE.

W = 11,500 A = 975,100. p = 23,172.
s = 44.376 in. = .0007004 r = 42.08 v = 15.53
Discharge (approx.) = 15,143,000.

WESTERN PASSAGE.

W = 9,600 A = 402,750. p = 19,344
s = .0007004 r = 20.82 v = 10.88
Discharge (approx.) = 4,382,000.

The enormity of such a flood can only be appreciated by comparison. It would be equal to a stream having a discharge six times as great as the Amazon, thirty-two times as great as the Mississippi, 140 times that of the Nile, 190 times that of the Ganges, and from two to three times as great as the combined discharge of all the rivers of the earth at the present time.

Ablation Demanded.—The impossibility of such a flood is clearly shown by the great amount of ablation which would be required to furnish the immense volumes of water demanded by the theory. The conditions favorable to a concentration of glacial drainage in Narragansett bay were no more favorable than at a dozen other points in New England, and the streams entering at this point could have comprised only a small part of the total number in the region in ques-

tion. The easternmost lobe of ice covering the state of Maine and terminating along a line reaching from cape Cod eastward to Georges shoal was, in its lower portion at least, almost entirely independent of the ice to the westward, and possessed without doubt a drainage system complete in itself. It could have furnished no part of the waters discharged through Narragansett bay.

The area of New England, excluding Maine, is approximately 33,500 square miles. Assuming the whole to have been covered with ice, a melting of 3.49 cubic feet of ice per day for every square foot in this area would have been required to furnish the flood demanded.

It should not be forgotten, however, that the conditions for great floods were just as favorable in the valleys of the Housatonic, Connecticut and Thames, and the area drained by the streams entering Narrangansett bay would not, in all probability, have been more than a quarter of the area mentioned above. Assuming the actual area drained to have been equal to that of the state of Massachusetts (8,315 sq. m.), we find the ablation required to meet the demands of the flood reaching the enormous figure of 14.1 cubic feet per day for each square foot of surface.*

Comparatively few measurements of the surface ablation of glaciers have been recorded, but enough is known to show conclusively that at the outside, it cannot be more than a few inches per day. Reid, in his report on "Glacier Bay and its Glaciers"† states that during the cloudy and rainy weather of the month of July the surface melting varied from 1.6 inches to 2.5 inches per day, while on a clear, bright day it reached as high as 2.75 inches per day. When it is remembered that during the Alaskan summer the thermometer often mounts well up towards the 100° mark, it will be readily seen that under no combination of circumstances could such a melting as that postulated in the preceding paragraph take place.

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*If, instead of assuming the whole of New England to have been covered at this stage of the ice retreat, we should regard the margin as occupying the position assigned by Upham (Amer. Geol., vol. XVI, plate v,) to the Toronto boundary, the area supplying water by ablation would be much decreased, and the amount of melting required to meet the demands of the hypothesis would be even more enormous than that given above.

†16th Ann. Rept. U. S. Geol. Surv. part 1, p. 450.

Transporting Power.—Additional evidence against the existence of such a torrent as has been described is found in the size of the material of which the sand-plains are composed. The predominating material is sand, and could only have been deposited in a current moving at a rate of less than one foot per second. Further back, and nearer the point of emergence of the glacial stream from the ice, the material becomes coarser, the sand giving place to fine gravel and indicating, perhaps, a current of two feet per second. Still nearer the head of the plain gravel is found indicating currents of three, four or even five feet per second, while in the esker left by the stream, as for example, the Barrington stream, stones up to six inches in diameter, and indicating a current of a little less than 6.4 feet per second, were observed.

The evidence of the material thus fixes a maximum to the actual velocities of the waters in which the sand plains were laid down. With this velocity the velocities necessitated by the assumptions of glacial floods as a cause for the hight of the waters in Narragansett bay in Champlain times, forms a striking contrast. As we have seen, the highest velocity indicated by the material of the sand plains is about six feet per second, a velocity which would be capable of moving almost exactly 17 pounds. The actual velocity of the postulated flood would, in the region of the sand-plains be 11.18 feet per second, and would be sufficient to roll along boulders 505 pounds in weight, or thirty times the size of the largest material of the sand-plains. In the Eastern passage the current would have been sufficient to have transported a boulder over two tons in weight, or about 240 times the size of the material at the head of the plains.

Problem of Ice Barriers.—An increase in the hight of the waters by simple flood demands torrents far beyond the range of possibility. Ice barriers, in the sense ordinarily used, are admittedly out of the question. Only barriers formed by the temporary gorging action of floating ice need, therefore, be considered.

The ice if in motion, would undoubtedly furnish an abundance of icebergs wherever it came in contact with the water. It is, however, a well known fact that such was not the case at the time of the deposition of the sand-plains, distortion,

crushing, or thrust faulting in the beds laid down against the face of the ice being almost unknown, and indicating that in practically every instance the ice was perfectly stationary. Occasional blocks were undoubtedly broken off, as is testified by the rock fragments dropped from them into the finely stratified material over which they floated, but the conditions along the front of such a stagnant icesheet were certainly unfavorable to any considerable discharge of floating ice.

Even where barriers of floating ice form in our narrow rivers they seldom last but a few days. Certainly an ice barrier of this type in the lower Narragansett bay would have been too transitory to have withstood the force of the enormous body of water pressing against it from behind for a period long enough for the deposition of a large sand-plain, however rapid this may be.

Summary.—In the foregoing pages the aim has been to follow to the logical end the results which must, of necessity, follow the disbarment of the submergence theory and the acceptance of the theory of glacial floods as an explanation of the altitude held by the waters of the Narragansett bay region during the final retreat of the ice. Evidences of a Champlain submergence along Long Island sound of at least fifteen feet are indisputable, and the actual amount was probably somewhat greater. The difficulty, however, of correlating this submergence as to exact time with the deposition of the Narragansett sand-plains detracts considerably from the value of arguments from such general evidence.

The level of the sea remaining substantially as at present, as is assumed by the advocates of the glacial floods, no considerable increase in the hight of the waters of the bay could take place unless more than sixty glacial streams of the size of the Barrington stream entered the bay simultaneously. The united volumes of these streams would be equal to six times the volumes of discharge of the Mississippi river. But the actual rise to be explained is at least fifty feet. This would necessitate, as has been shown, the discharge into the bay of a flood amounting to over 19,500,000 cubic feet per second, an amount requiring the ablation of at least 3.49 cubic feet of ice, and probably of 14.1 cubic feet per day, for every square foot of its drainage area. Such a torrent would have a

transporting power of from 30 to 240 times that indicated by the coarser materials of the sand-plains.

The existence of such floods is untenable, as must also be the theory which demands them. Recourse to the theory of the existence of barriers formed by the gorging action of floating ice is unavailing. for the conditions during the retreat of the ice sheet were manifestly unfavorable to their formation. Even the complete closing of one of the passages would, moreover, affect but little the conditions of the flood.*

Conclusion.—The failure of the glacial-flood and the ice-barrier theories to afford a satisfactory explanation of the phenomena in Narragansett bay brings us by the process of elimination to the alternative theory of submergence. The fact that the great over-wash plains on the south side of Cape Cod were undoubtedly of subaërial formation, has had the effect of causing many of the workers in this region to disregard the evidences of submergence, which are certainly quite manifest in places and to magnify the evidences to the contrary.

The plains of the outer arm of Cape Cod were certainly deposited in standing water, but whether the deposition took place in the sea or in a body of fresh water ponded against the moraine,† is a matter of dispute. The writer believes strongly in the former, the low and broken character of the moraine—especially in that portion lying in the vicinity of the sand plains, where perfect continuity is most essential—being most unfavorable to the theory of ponding. But whatever doubt there may be as to this point, there can be none in regard to many of the plains of Buzzards bay. The case here is perfectly clear and can only point to a submergence amounting, apparently, to at least forty feet. It was this evidence which first led me to take issue with the views of submergence held by Davis, Woodworth and others.‡ That I

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*The actual decrease in discharge which would have been brought about by the complete closing of the Western passage would have been only about 1,200.000 cubic feet per second, or some 6.5 per cent.

†A. W. Grabau, Science, n. s. vol. X, p. 334-5.

‡The views here advanced as to submergence in the regions of cape Cod and Buzzard's bay were first set forth in an unpublished essay on the "Modified Drift of Cape Cod" which received first award in competition for the Walker prize offered by the Boston Society of Natural History for 1897.

have based the arguments of this paper upon Naragansett, rather than upon Buzzards bay, is due to the fact that it is only in the former case that any detailed description of the sand plains has been published.

The theory of submergence would be much simplified in its application to the Narragansett bay region if it were possible to regard the Greenwich Cove and Barrington stages as contemporaneous. This Mr. Woodworth regards as improbable. The irregularity of the ice margin demanded under these conditions is no more than that shown by plains in other localities, and is at least within the range of possibility. The tendency to long north and south depressions held open by the ice in the region in question is by no means unfavorable to the theory.

REVIEW OF RECENT GEOLOGICAL LITERATURE.

The Geological Structure of Shantung (Kiautschou) with particular reference to the deposits of useful minerals. [Der geologische Bau von Schantung (Kiautschou) mit besonderer Berücksichtigung der nutzbaren Lagerstätten.] By **Ferdinand v. Richthofen.** (Zeitschrift für praktische Geologie, pp. 73-84, March, 1898.)

This article by privy councillor Dr. Ferdinand von Richthofen upon the economic geology of the Shantung peninsula of China is of especial importance at the present time because of the recent acquisition of the part of Kiaochau by Germany. From this article we take the following:

The province of Shantung was visited by Ferdinand v. Richthofen at the beginning of his travels in China in the year 1869. No geological investigations had been made prior to that time, and since there was also no reliable topographical map he was compelled to make one himself. The scale of Richthofen's map is 1:437,000. It also appears on a smaller scale in his atlas of China in which Shantung appears on pages 1 to 4 and 53 and 54.

The province is chiefly level ground, a part of the great plain of China, only about 2/7 of its area being mountainous. The mountain chain surrounds the entire peninsula and extends westward across it forming an island-shaped area enclosed by plain and sea. The great plain is an eruptive table-land and the underlying rocks are of unknown age. The surface features are sculptured by the Hwang-ho and other streams, each of which has at some time been one of its tributaries.

The great plain is an eastward sloping delta or alluvial deposit of this great river system.

The Wei river in its northward course divides the mountain region into two portions geologically and orographically distinct from each other. The elevations are not of much magnitude. The Tai-shan in the western part reaches the hight of 1,600 meters with occasional ridges in its vicinity 1,200 to 1,300 meters high. East of the river the elevations are lower, but the mountains are precipitous and wild. A chain of mountains, much cut into by deep arms of the sea, follows the southern coast of the peninsula. Between the foothills of the Lauschan with its elevation of 1,090 meters and the western continuation of the range lies Kiaochau bay, a circular basin 26 kilometers in diameter and with a depth of more than 40 meters of water.

Toward the north from here there extends a broad gently undulating lowland reaching the northern coast of the peninsula. It extends also far toward the east into the mountains, but consists of decomposed rock-material rotted down in place rather than of alluvium. This region supports the most prosperous and populous communities.

The mountain region of Shantung consists geologically only of old formations; folded Archean rocks at the bottom and Paleozoic schist formations free from folding and metamorphism above. The lowest rocks are primary gneisses and granites and hornblende schists penetrated by pegmatyte and quartz veins. Then follow crystalline schists and limestones. Granite eruptions (Korea granite) accompanied the active and intense mountain-making phenomena. The greater portion of the superincumbent and little disturbed Paleozoic schist massif is included in the so-called "Sinisch" (Cambrian) formation. In its lower portion are found coarse conglomerates and sandstones; in the middle are quartzose sandstones and clay slates interbedded with flat limestones; in the upper horizons limestones predominate and are characterized by the oölitic structure.

Unconformable upon these strata follows the Carboniferous, the Silurian and Devonian being apparently absent. The Carboniferous begins with limestone: then follow calcareous, occasionally fossiliferous but usually rather sandy clay slates. With the uppermost members are found porphyries and porhypritic tuffs of Permian age or younger. This completes the series of the older formations. The covering consists of the loess which rests upon all valleys, slopes and low hills.

As is shown on the map published in the "Zeitschrift für praktische Geologie," p. 77, east and west Shantung differ from each other geologically and orographically. Upon the eastern side the Coal Measures are wanting and the "Sinisch" is not prominently developed; on the west the strata of the latter formation have a great development and the Carboniferous is abundantly in evidence. Toward the west the crystalline rocks do not form prominent features of the landscape; on the east they predominate. In western Shantung the loess covering is universal; in eastern Shantung it is rare.

This important dividing line between east and west Shantung is a

part of the great boundary line between Liautung and Shantung, which is also marked by a chain of volcanic eruptives.

In eastern Shantung where gneiss and granite-gneiss prevail there are evidences of a double folding, one in the normal strike of the gneisses from north-northwest to south-southeast, and the other parallel with the strike of the "Sinisch" formation, from west-southwest to east-northeast.

The mountain region of the west half is composed of a great number of extensive table-like terraces each of which is raised up on one side and consists of a crystalline foundation with a capping of "Sinisch" sediments. The terraces dip in minor folds in a northern direction; but the lines of fracture have different strikes. There seems to be a tendency toward a radial arrangement with the Tai-shan as a center, while small breaks running at right angles accompany the radial folds, and on the northern edge of the mountain region small fractures produce deep gorges.

There is a close relation between this orographic structure and the occurrence of the coal beds which are shown on the map already mentioned. The geological structure which is interpreted as far as is already known on the map published on page 75 of the Zeitschrift für praktische Geologie, is not yet fully understood. It is probable, however, that we have here the remnants of a formerly extensive sedimentary series which has been subjected to profound erosion. Its continuation underneath the younger sediments of the region may probably be demonstrated by a careful study.

The coal fields already show several beds of most excellent coal of workable dimensions. They are always found interstratified with limestone and clastic rocks. In the original article are excellent accounts and profiles of the coal deposits of Po-shan (several seams of from 6 to 8 feet in thickness), Tschung-Kiu (several veins from 4 to 6 feet thick), Wei-hsien (veins 3 to 6 feet thick), I-tschou-fu and I-hsien probably seven veins up to 5 feet thick).

The first coal field has a considerable but not completely surveyed area. Its continuation may be looked for toward the east and south underneath the tuffs which occur in those directions. A careful geological study would throw important light on this subject.

There are also iron ores in the district of I-tschou-fu which, notwithstanding their richness, have not yet been worked. Another iron ore deposit is found east of Tsinan-fu. It is a typical contact deposit and owes its origin to intrusions of dioryte.

The future of the province of Shantung and Germany's new Chinese possession depends according to F. v. Richthofen upon the extensive coal fields. The other metallic riches, of which so many exaggerated tales are told and which are so graphically portrayed on maps of the province, are limited to traces of gold in the alluviums and small amounts of galenite and copper sulphurets in the Archean mountains.

But the future of Kiauchau lies chiefly in its role as a diverging point for railroads. The coal fields of Shantung will be opened by

them and rendered accessible to the harbors. The coal fields are favorably situated and the deposits are extensive enough to reward development and the structure of the coal makes it excellent for use by steamships. The most important point, however, is that in all of southern and eastern Asia (vide Zeit. f. prakt. Geol. 1894, pp. 37, 39 and 254; 1897, p. 389) there is no place where equally good stone coal occurs so near to a good shipping point. The great and celebrated coal fields of China lie far inland; Kaiping alone is near the coast, but the voyage thither is a long one and there is no good harbor. The Mesozoic coals of Japan and Formosa are much inferior in structure to those of Shantung and the Tertiary coals of Indian Asia are not to be compared with them.

The route of the railroads has been officially decided. A road to Wei-hsien, from there westward toward the northern boundary of the mountains toward Poschan-hsien and Tsi-nan-fu would make the northern coal fields of the series tributary to the harbor. The construction of that part which lies in this unusually populous and productive territory would be easy and inexpensive on account of the extremely low cost of labor. A further road would have to be constructed in a western direction toward I-tschou-fu. If the iron ores at this latter point should prove worthy of exploitation the place would acquire considerable importance. Connection of this place by a road past Yentschoufu to Tsi-nan-fu would for the present give a very favorable terminal for the whole system of railroads.

Until now the coal was almost unavailable. Upon the opening of the harbor of Kiauchau and the building of the railroad lines mentioned depends the future of the rich and as yet partly unexplored coal fields of Shantung. H. V. WINCHELL.

Water Resources of Indiana and Ohio. By FRANK LEVERETT. (From the Eighteenth Annual Report, U. S. Geol. Survey, for 1896-97; Part IV, Hydrography, pp. 419-559, with plates xxxiii-xxxvii, and figures 76, 77.)

During the author's extensive explorations of the marginal moraines and other drift deposits of these states, he has collected, as another branch of his work, the large amount of exact and well arranged information which he gives in this memoir concerning the drainage systems, lakes, underground waters, springs, and water supplies of the cities and villages. One of his maps shows the contour of the district; another, its stratified rock formations; a third, the Pleistocene deposits; and a fourth, the relation of the drift to the ordinary wells. Complexly looped and interlocked moraines, to the number of ten or twelve, traverse Indiana and Ohio, with large intervening areas of till plains. Older till, covered by loess, is mapped extending southwest, outside the moraine belts, nearly to the mouth of the Wabash, and across the Ohio river in the region of Cincinnati; but each state also has large areas in its southern part beyond the limits of the drift, excepting the water-borne modified drift of the river valleys which head within the glaciated area. The memoir will be of great interest and practical value to the people of these states. It raises an earnest hope that Mr. Leverett's detailed studies of the drift there will be as fully published at no distant time. W. U.

New Developments in Well Boring and Irrigation in Eastern South Dakota, 1896. By NELSON HORATIO DARTON. (From the Eighteenth An. Rep., U. S. Geol. Survey; Part IV, pp. 561-615, with plates xxxviii-xlvii, and figures 78-85.)

The present report is supplementary to the paper by Mr. Darton on the artesian waters of the Dakotas in the last preceding annual report of this Survey. During the year 1896, numerous additional wells were sunk for artesian water, chiefly to be used for irrigation, in the region of South Dakota adjoining the Missouri river, from which it is predicted that good artesian flows from the Dakota sandstone will be obtained by deep wells in this valley as far northward as Bismark. Log records of many of the wells are given. A very remarkable increase of underground temperature at the moderate depths of the wells (mostly from 500 to 1,500 feet deep) is shown by the temperature of their water. The downward increment of heat is one degree Fahr. for each 17½ feet at Fort Randall, and the whole artesian district has a range from about 20 to 45 feet for each degree, in contrast with an average elsewhere, throughout the world, of about 50 feet for a degree. The causes of this anomalous condition, in a region so far from any recent volcanic action and undisturbed by orogenic processes, are not yet ascertained. W. U.

MONTHLY AUTHORS' CATALOGUE
OF AMERICAN GEOLOGICAL LITERATURE, ARRANGED ALPHABETICALLY.*

Agassiz, Louis.

[Various articles on Agassiz and his work.] By A. S. Packard, G. F. Wright, D. S. Jordan, C. R. Eastman, G. C. Davenport, B. G. Wilder, and others. (Am. Nat., vol. 32, pp. 147-199, Mch. 1898.)

Bain, H. F.

The Aftonian and Pre-Kansan deposits in southwestern Iowa. [Abstract.] (Am. Geol., vol. 21, pp. 255-262, Apr. 1898.)

Brigham, A. P.

Note on trellised drainage in the Adirondacks. (Am. Geol., vol. 21, pp. 219-222, pl. 15, Apr. 1898.)

Calvin, Samuel.

The interglacial deposits of northeastern Iowa. [Abstract.] (Am. Geol., vol. 21, pp. 251-254, Apr. 1898.)

Chalmers, Robert.

The pre-glacial decay of rocks in eastern Canada. (Am. Jour. Sci., ser. 4, vol. 5, pp. 273-282, Apr. 1898.)

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*This list includes titles of articles received up to the 20th of the preceding month, including general geology, physiography, paleontology, petrology and mineralogy.

Dall, W. H.

The future of the Yukon gold fields. (Nat. Geog. Mag., vol. 9, pp. 117-120, Apr. 1898.)

Dana, J. D.

Revised text-book of geology. Edited by W. N. Rice. (Pp. ix and 482; American Book Co., New York.)

Darton, N. H.

New developments in well boring and irrigation in eastern South Dakota, 1896. (U. S. Geol. Survey, 18th Ann. Rept., pt. 4, pp. 561-615, pls. 38-47, 1897.)

Dawson, J. W.

On the genus Lepidophloios as illustrated from specimens from the coal formation of Nova Scotia and New Brunswick. (Roy. Soc. Canada, Trans., ser. 2, vol. 3, sec. 4, pp. 57-78, pls. 1-14, 1897.)

Derby, O. A.

Brazilian evidence on the genesis of the diamond. (Jour. Geol., vol. 6, pp. 121-146, Feb -Mch. 1898.)

Drake, N. F.

A geological reconnaissance of the coal fields of Indian Territory. (Leland Stanford Junior Univ. Pub., Contributions to Biology from the Hopkins Seaside Lab., XIV, 1898. Reprinted from Am. Phil. Soc., Proc., vol. 36, pp. 326-419, pls. 1-9, Dec. 1897.)

Eastman, C. R.

Agassiz's work on fossil fishes. (Am. Nat., vol. 32, pp. 177-185, Mch. 1898.)

Emmons, S. F.

Alaska and its mineral resources. (Nat. Geog. Mag., vol. 9, pp. 139-172, Apr. 1898.)

Farrington, O. C.

Datolite from Guanajuato. (Am. Jour. Sci., ser. 4, vol. 5, pp. 285-288, Apr. 1898.)

Foote, H. W. (Penfield, S. L. and)

On clinohedrite, a new mineral from Franklin, N. J. (Am. Jour. Sci., ser. 4, vol. 5, pp. 289-293, Apr. 1898.)

Frazer, Persifor.

Archean character of the nuclei of the Antilles. (Am. Geol., vol. 21, pp. 250-251, Apr. 1898.)

Goodrich, H. B.

Recent warpings as shown by drainage peculiarities [in Yukon district]. (U. S. Geol. Survey, 18th Ann. Rept., pt. 3, pp. 276-289, pls. 43-44. 1898.)

Goodrich, H. B.

History and condition of the Yukon gold district to 1897. (U. S. Geol. Survey, 18th Ann. Rept., pt. 3, pp. 103-133, 1898.)

Guthrie, Ossian.

A view and description of the bed of a prehistoric or glacial lake, between Summit and Lamont, Ill. (Jour. West. Soc. Engineers, vol. 3, p. 815. Feb. 1898.)

Hidden, W. E., and Pratt, J. H.

On rhodolite, a new variety of garnet. (Am. Jour. Sci., ser. 4, vol. 5, pp. 294-296, Apr. 1898.)

Jaggar, T. A., Jr.

An occurrence of acid pegmatyte in diabase. (Am. Geol., vol. 21, pp. 203-213, pl. 14, Apr. 1898.)

Keyes, C. R.

The use of local names in geology. (Jour. Geol., vol. 6, pp. 161-170, Feb.-Mch. 1898.)

Keyes, C. R.

Use of the term Augusta in geology. (Am. Geol., vol. 21, pp. 229-235, Apr. 1898.)

Knowlton, F. H.

Report on a collection of fossil plants from the Yukon river, Alaska, obtained by Mr. J. E. Spurr and party during the summer of 1896. (U. S. Geol. Survey, 18th Ann. Rept., pt. 3, pp. 194-196, 1898.)

Leverett, Frank.

Water resources of Indiana and Ohio. (U. S. Geol. Survey, 18th Ann. Rept., pt. 4, pp. 419-559, pls. 33-37, 1897.)

Leverett, Frank.

The weathered zone (Sangamon) between the Iowan loess and Illinoian till sheet. (Jour. Geol., vol. 6, pp. 171-181, Feb.-Mch. 1898.)

Leverett, Frank.

The weathered zone (Yarmouth) between the Illinoian and Kansan till sheet. [Abstract.] (Am. Geol., vol. 21, p. 254, Apr. 1898.)

Leverett, Frank.

The weathered zone (Sangamon) between the Iowan loess and Illinoian till sheet. [Abstract.] (Am. Geol., vol. 21, pp. 254-255, Apr. 1898.)

Merrill, G. P.

Notes on the geology and natural history of the peninsula of Lower California. (U. S. Nat. Museum, Rept. for 1895, pp. 969-994, pls. 1-10, 1897.)

Penfield, S. L., and Foote, H. W.

On clinohedrite, a new mineral from Franklin, N. J. (Am. Jour. Sci., ser. 4, vol. 5, pp. 289-293, Apr. 1898.)

Pratt, J. H., (Hidden, W. E., and)

On rhodolite, a new variety of garnet. (Am. Jour. Sci., ser. 4, vol. 5, pp. 294-296, Apr. 1898.)

Preston, H. L.

San Angelo meteorite. (Am. Jour. Sci., ser. 4, vol. 5, pp. 269-272, Apr. 1898.)

Ries, Heinrich.

Allanite crystals from Mineville, Essex county, N. Y. (N. Y. Acad. Sci., Trans., vol. 16, pp. 327-329, 1897.)

Ries, Heinrich.

Note on a beryl crystal from New York City. (N. Y. Acad. Sci., Trans., vol. 16, 1 p., 1897.)

Riggs, E. S.

On the skull of Amphictis. (Am. Jour. Sci., ser. 4, vol. 5, pp. 257-259, Apr. 1898.)

Sederholm, J. J.

The geology of the environs of Tammerfors. [Translated from the guide to the excursions of the Seventh International Congress of Geol-

Some preglacial soils. [Abstract.] Am. Geol., vol. 21, pp. 262-264,

Smyth, C. H., Jr.

Weathering of alnoite in Manheim, New York. (Geol. Soc. Amer., Bull., vol. 9, pp. 257-268, pl. 18, Mch. 28, 1898.)

Spurr, J. E.

Geology of the Yukon gold district, Alaska. With an introductory chapter on the history and conditon of the district to 1897, by H. B. Goodrich. (U. S. Geol. Survey, 18th Ann. Rept., pt. 3, pp. 87-392, pls. 32-51, 1898.)

Squier, G. H.

Studies in the driftless region of Wisconsin. II. (Jour. Geol., vol. 6, pp. 182-192, Feb.-Mch. 1898.)

Turner, H. W.

Description of the Downieville folio. (U. S. Geol. Survey, Geologic Atlas of the U. S., folio 37, Downieville folio, Calif., 1897.)

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CORRESPONDENCE.

On the Formation of New Ravines. In the ninth edition of his "Principles of Geology" Sir Charles Lyell describes a ravine near Milledgeville, Georgia, which was excavated in twenty years to a depth of 55 feet. A part of his account follows:[*]

"When travelling in Georgia and Alabama, in 1846, I saw in both those states the commencement of hundreds of valleys in places where the native forest had been recently removed. One of these newly formed gulleys or ravines is represented in the annexed wood cut from a drawing which I made on the spot. * * * Twenty years ago, before the land was cleared, it had no existence; but when the trees of the forest were cut down, cracks three feet deep were caused by the sun's heat in the clay, and, during the rains, a sudden rush of water through the principal crack deepened it at its lower extremity, from whence the excavating power worked backward, till, in the course of twenty years, a chasm measuring no less than 55 feet in depth, 300 yards in length, and varying in width from 20 to 180 feet, was the result."

The figure which Lyell publishes shows a great gully with precipitous walls. The walls, bottom and surface of the immediately adjacent country are represented as bare of trees. A wooded hight is seen in the distance, and a few scattering trees are shown, but all at a considerable distance from the edge of the ravine. The trees depicted are those only which have the outline and habit of broad-leaved kinds, none of them are pines and none are near the edge of the ravine.

Over fifty years have passed since Lyell wrote his description of this phenomenon. Finding that Lyell's description is still quoted,[†] and having some curiosity to know what erosion had been accomplished since Lyell wrote, it occurred to me a short time ago to write to Milledgeville for information regarding the present condition of the ravine. A few days ago I received an excellent description of the ravine from Mr. J. Harris Chappell, president of the Georgia Normal and Industrial College, who, in company with Prof. Beeson, had paid a visit to the gully on the Saturday before, viz., Jan. 22. Following is a part of Pres. Chappell's letter:—

"The 'Big Gully,' by which name it is familiarly known, is situated four and one-half miles from Milledgeville on a high ridge of hills overlooking the town. The gully is 320 yards long, varies from 80 feet to 300 feet in width, and is 65 feet deep in its deepest part. From the main stem springs four zig-zag branches, making of the whole quite a complex ramification. I should say that the whole wash-out covers an area of about ten or twelve acres. * * * In some places the gully is covered with a thick forest growth, mainly pine trees, some of

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[*] The description stands in the 11th and last edition exactly as in the 9th edition p. 204. vol. I, p. 338.

[†] Vide Merrill's "Rocks, Rock Weathering and Soils," 1897, p. 396.

them fifty or sixty years old, I should say. In the bottom of the deepest part we measured a pine tree nearly 4½ feet in circumference. * * * At present the gully seems to be at a standstill. I can perceive no change in it during the six years that I have been living in Milledgeville, though I confess I have not observed very closely. Through the bottom of the gully, for nearly its full length, runs a tiny stream not wider than your three fingers, coming from a spring, perhaps; otherwise the entire excavation is as dry as a bone. Immediately around the gully is a fringe of woods, the original forest growth, I suppose; but less than a hundred yards away on all sides are cleared and cultivated fields."*

In addition to the written account of the present condition of the ravine Pres. Chappell sent four photographic views which he had taken on the occasion of his visit to the locality, which supply certain valuable details. These views show a fringe of trees, principally pines, bordering the ravine. The tallest of these trees seem to be somewhat less in hight than the walls of the ravine. In at least two of the views there are trunks of trees lying on and against the side of the ravine in such positions as to show that they have fallen from above, and several others are standing at the very brink of the chasm, with bared roots from which the earth, into which they once grew, has fallen away. It is quite evident, from a study of these views in the light of Lyell's description of the locality, that the trees which now border the ravine, have grown within the last fifty years, and furnish an explanation to the very natural question, why the wear has not been proportionally as great in the fifty years from 1846 to 1898 as it was in the twenty years prior to 1846. They show also what is of interest in the consideration of the influence of forests on soil, that is, the conserving power of trees to prevent loss and other destructive results to the soil through erosion. Whether this fringe of trees was planted by the land owners, or whether the trees were allowed to stand, having sprung up after the original forest covering was removed, or whether some of them are a remnant of the original forest, they now stand as a barrier to prevent the too rapid encroachment of the ravine on the adjacent fields.

Washington, Pa., Feb. 2, 1898. EDWIN LINTON.

PERSONAL AND SCIENTIFIC NEWS.

PROF. W. P. BLAKE, director of the Arizona School of Mines at Tucson, has been appointed, by the governor, territorial geologist of Arizona.

THE SOCIETE GEOLOGIQUE DE BELGIQUE will celebrate its 25th anniversary at Liége in September. Excursions will be

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*Letter dated Jan. 24th, 1898.

given to interesting geological localities in the vicinity. And invitations have been sent to the honorary members in the U. S. and elsewhere to be present and contribute to the interest of the occasion.

THE RUSSIAN PROVINCE OF KURSK proves to be one of the most remarkable areas of magnetic disturbance yet known. M. Moureaux reports that the differences between theory and observation are so great that it is not possible to draw isomagnetic lines, and the magnetic force is as great as it would be in the immediate vicinity of the magnetic poles.

IT IS A REMARKABLE FACT that of over 100 finds of iron meteorites only nine have been seen to fall, while of over 400 finds of stony meteorites more than one-half have been seen to fall. Mr. H. L. Preston finds several reasons for believing that the iron meteorites are merely the crystallized metallic nodules contained in the larger and more conspicuous stony meteorites.

PROFESSOR AGASSIZ of Harvard has arrived at San Francisco after an absence of some months in the South Seas spent in studying the formation of the coral islands. It is said that he is prepared to demonstrate, in opposition to the theories of Darwin and Dana, that the coral islands are not built up from the bottom, but are formed by a comparatively thin crust of coral upon tops of submerged mountains at points where the ocean is comparatively shallow. In nearly every instance where borings have been made in the coral the coral has been found to be shallow. At a few places where it seems to have great depths Professor Agassiz says that the material into which deep borings are made is lime of a former age of the earth.

THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE will hold its fiftieth anniversary meeting in Boston on August 22nd to 27th. Every preparation is being made to make this meeting of great interest, and it is hoped that it will be the largest and most enthusiastic meeting yet held. The members of the local committee are making elaborate arrangements for entertaining the Association, and a number of excursions to points of interest will be given. The president elect, Prof. F. W. Putnam of Salem, Mass., who has been permanent secretary of the Association for twenty-five years, will retain that position until the Boston meeting. The officers of section E, geology and geography, are: Vice president, Prof. H. L. Fairchild, University of Rochester, Rochester, N Y.; Secretary, Mr. Warren Upham, Minnesota Historical Society, St. Paul, Minn.

COPPER IN LAKE SUPERIOR IRON MINES. Two or three years ago some copper minerals, including the native metal,

were found in small quantities in the Montana mine, at Soudan, Minn., on the Vermilion iron range. (See this journal, vol. 19, p, 417). Now it is reported that a body of native copper weighing several tons has been found in the same mine at a depth of 700 feet from the surface.

MARYLAND GEOLOGICAL SURVEY. The Maryland legislature, in addition to passing the regular appropriations of $20,000 for the state geological survey, has also appropriated to the same organization $10,000 for topography and $20,000 for the study of the question of road construction in the state. The latter act calls for the investigation of and report upon the character and distribution of the natural road building materials in the several counties and a full statement regarding the present condition of the roads and the best means for their improvement, with estimates of cost of constructing, repairing and maintaining the same. Such universal approval has been accorded by the people and press of the state to the geological survey that the acts passed both houses unanimously. The entire appropriation has been placed under the direction of Prof. Wm. B. Clark, of John Hopkins University, the state geologist. (*Science.*)

JULES MARCOU died at his home in Cambridge, Mass., on April 17th. He was born in France on April 20th, 1824, and had thus almost completed his 74th year. Prof. Marcou is well known both in Europe and in America, his adopted home, from his geological work and writings. His geological map of the United States and his early publications on the geology of the southwestern states, especially on the Mesozoic, have made him an important factor in the development of geological knowledge in the United States. He was associated with Louis Agassiz, and a few years ago published a life of that distinguished naturalist.

MR. MARCUS BAKER delivered the annual address before the Philosophical Society of Washington on April 2nd. The subject was "A century of geography in the United States."

A. DES CLOIZEAUX. A biographical notice of this distinguished French mineralogist was read by Prof. A. Lacroix before the French Society of Mineralogy at the meeting of Dec. 9, 1897. This notice, accompanied by a portrait and a bibliography, appears in the last number of the Bulletin of the Society (vol. 20, no. 8, Dec., 1897).

POPOCATEPETL AND ORIZABA. The various determinations of the hights of these two great Mexican mountains are given by Mr. A. E. Douglass in "Appalachia" for March, 1898. Omitting a number of the least reliable determinations and getting the mean of the others, Mr. Douglass gives the altitude of Popocatepetl as 17,660 feet with a possible error of 50 feet, and of Orizaba as 18,240 feet with a possible error of 100 feet.

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PALEOLITH AND NEOLITH.

By DR. E. W. CLAYPOLE, Akron, Ohio.

The above terms were introduced into archæology by Sir John Lubbock in order to accentuate a distinction previously felt rather than expressed among the stone implements found at different prehistoric dwelling-sites in England. The distinction rests mainly on the single fact that the relics of certain groups—the palæolithic—have been shaped entirely by chipping and never show a trace of rubbing or grinding while in other groups—the neolithic—both methods of fashioning the tools or weapons have been employed. The presence of a ground edge or a rubbed face is accordingly a crucial test for distinguishing the two types.

The value of the terms was at once recognized and the progress of time and investigation has only rendered them more useful and important. To some extent also the distinction has gained a geographical significance and a large area in northern and northwestern Europe has been delimited over which it prevails with as great clearness as in England. Outside of this region however, for reasons which will appear later, it cannot always be traced with equal certainty. In fact it becomes less and less sharp with increasing distance from the typical center. It is, however, frequently practicable even in distant places to determine from internal evidence the palæolithic nature of certain "finds" and the neolithic character of others.

But the fundamental distinction above mentioned, to express which the terms were invented, has been supplemented by several other secondary ones of almost equal importance. Some of these are obvious, others can scarcely be detected save by an experienced eye. Space will not allow a lengthened explanation here. A mere mention must suffice. Then the material of the palæolith is almost always flint of some kind; in the neolith other stones are employed; the pattern of the former is heavier and coarser than that of the latter; the edge shows little or no secondary chipping; the implement was often made by a single stroke and is triangular in section; and last, though not least, the surface shows a peculiar luster or "patina" due to age and secondary deposition of silica that is never seen on newly chipped flints and which it is impossible to imitate.

By the consideration of these characters or of such of them as may occur in any specimen it is seldom difficult to determine whether a collection of flint weapons is of palæolithic or of neolithic age. At the same time it must be borne in mind that implements showing some palæolithic characters frequently occur among others decidedly neolithic, a circumstance which need cause no surprise. On the other hand neolithic implements cannot of course be met with at truly palæolithic stations. The obvious signification of this is that the older pattern and material survived into the later time and were still employed for certain purposes after the newer fashion of grinding had been introduced and other materials than flint had been adopted.

Slight as the difference may seem between chipping and grinding it implies nevertheless an immense advance in art and an immense lapse of time. The intensely slow progress of man in those early days can scarcely be realized by any who have not studied the vast time-intervals of even Quaternary geology and the stereotyped, non-progressive condition of savage life. The arts possessed by neolithic man, of which his palæolithic predecessor in England was ignorant, implicitly prove to the student of anthropology the passage of almost countless years or even centuries during which the race was groping in the dark along the rough, steep path of progress, profiting by accidents, led by curiosity and taught by bitter

and costly experience. From the naturally broken flint to the ground axe of greenstone may seem an easy transition, but historically it was long and difficult, the outcome of trials and failures innumerable, of changed environment, of conflict, struggle and death.

Nor is this surprising to any one who notes the progress of mankind even at the present time. The history of science and art reveals a thousand cases in which men have so narrowly missed great discoveries or inventions that on looking back it seems impossible that they failed to see them. But so it was, and for another who came after were the renown and the recompense reserved. The effect of some preconceived idea, the limited reach of the human faculties, varying but never great, the difficulty of conceiving anything previously unknown, all these and other causes act as barriers in the way of progress which are only overpassed by some unusually gifted individual or broken down by the steady pressure of the general advance.

Slower still, without any means of recording and transmitting his experience except by word of mouth, was the advance of our primitive ancestor and in the single fact that palæolithic man was able to spread over all the eastern hemisphere and perhaps the western also we may read the immense duration of palæolithic time. By slow migration from land to land, contesting the ground with his great mammalian competitors, he was able to cover the old world and to leave his tools and weapons in every land before he succeeded in making the seemingly small advance that carried him over the barriers into neolithic time and neolithic conditions.

It may be well in passing to state some of these proofs of great advance during the lapse of the long ages that are indicated by the profound gap existing between palæolothic and neolithic time in Great Britain. Besides the differences in the weapons and his implements already mentioned we know that palæolithic man in England knew nothing of the potter's art, he had not domesticated any of the brutes, his companions, he practised no agriculture, built no dwellings, and was probably quite ignorant of the bow and arrow and of navigation. All the advantages were possessed by neolithic man on his first appearance in the region. Add these facts to the former and

no one can doubt that an immense gap in development exists between the two.

It was not easy to assign to this vast gap in English prehistory any sufficient cause or to show why so complete a break should exist in English archæology. Geology at length offered a solution of the problem which apparently meets every condition and is capable of removing every objection. Prof. James Geikie in his work on the "Great Ice Age," by an elaborate and powerful argument, urged and sustained an explanation which can hardly fail to commend itself to the scientific student of archæology. Prof. Geikie called attention to the fact that no palæolithic remains have been found in superficial deposits in that part of Britain which was covered by the ice of the last great ice-sheet or in his category the third recurrence of glacial conditions (Neudeckian). The few specimens hitherto reported have been found in caves or similar protected places. Outside of this region, however, in the eastern and southern parts of the island palæolithic remains occur in scores of spots on the very surface and in the gravels of the river-valleys. Consideration of this fact led Prof. Geikie to maintain that its most rational explanation is that palæolithic man, in at least the northern part of England antedated the last great ice-invasion and that the cause of the absence of his relics from the glaciated area is simply their destruction by the ice and the torrents flowing from the glacier. So simple an explanation and one sufficient to meet all the facts of the case seems to leave nothing to be desired even when estimated alone, but when all the other circumstances that cluster about it and confirm it are taken into account its rejection becomes impossible. Thus Prof. Geikie dwells on the important coincidence that what is true of palæolithic man is equally true of the remarkable southern fauna that lived in England at the same time. This fauna, semi-tropical in its character, included such animals as the hippopotamus, rhinoceros, southern elephant, hyæna and many other forms indicating a very warm climate. Their remains also are lacking in the glaciated area of northern Britain save under conditions that would protect them from the destructive action of the ice. Now it is well known that palæolithic man was a member of the south-

ern fauna and nothing therefore is more natural than that his remains and theirs should occur in like conditions and circumstances, and it is easy to see the strong confirmation which the coincidence lends to Prof. Geikie's interpretation.

Obviously this theory in a few words amounts to the proposition that palæolithic man is in Britain of interglacial age and that his remains are never found in truly post-glacial beds. I say "truly" because in a few cases it has not been possible to determine the exact dates and these must be set aside as furnishing no evidence in either direction. But wherever the age of the implement-bearing strata can be satisfactorily ascertained Prof. Geikie maintains that all those yielding palæoliths are of earlier date than the close of the ice-age and that all of later date invariably furnish implements of neolithic character.

There is now no difficulty in explaining the absence of palæoliths from the northern portions of the island, while neoliths occur in abundance over the whole. The latter are the remains of the population that came in after the final disappearance of the ice, while the former could only remain in that part which the ice did not reach. Both are consequently found in the south and southeast, but palæoliths occur there only.

Omitting for lack of space several other confirmatory facts that might be adduced no one can fail to note how satisfactorily Prof. Geikie's theory accounts for the "patina" or aged appearance upon the surface of a palæolith. It is not yet possible even to surmise with any confidence the relative ages of interglacial and postglacial deposits, but no geologist can entertain the smallest doubt that they are separated by an interval, measured in years, of enormous duration.

This is alone a very strong confirmation of the theory and combined with those previously mentioned cannot fail to commend it to the acceptance of archæologists, especially when they reflect that no other explanation of the facts has been put forward that can in any degree be compared with it for clearness and force.

In British archæology therefore palæolithic man and glacial or interglacial man are synonymous terms, while neolithic

man is in all cases of postglacial and consequently very much later date.

It is not at present possible to apply the same distinction to the human remains found in North America. No case has yet been brought forward in which the tools or weapons of man have been found in such circumstances as to allow the belief that they were of interglacial age. Without entering here into details it will be sufficient to say that the most ancient and authentic of them make no claim to be of older date than the gravels of the last great glacial advance. The stone weapons of Ohio, Minnesota, New Jersey, etc., make no pretensions to greater antiquity than this. Viewed therefore according to the manner of British archæologists and geologists who accept the theory of Prof. Geikie they are all of postglacial and consequently of neolithic date, be their pattern what it may. Most of them, too, are of so distinctly modern a type, such as those from California and the New London axe,* that their neolithic character is obvious. Even the argillyte implements from New Jersey, probably the oldest yet described, cannot claim an antiquity greater than early postglacial. The same may be said of the spear-head from Newcomerstown, Ohio.

In view of the above statements it is very desirable to avoid altogether the use of the terms "palæolithic" and "palæolith" in reference to American prehistoric implements, at least until a good case is made out for an antiquity comparable with that of the genuine palæoliths of England. Almost all the former are essentially and unmistakably neolithic, and that term alone can characterize them. If, however, any should feel dissatisfied with a word of so wide a signification and desire one of more restricted meaning I would suggest that "*pro-neolith*" may be applied to those relics which show by their association with glacial beds that they are very closely connected in date with the retreat of the ice, leaving the older

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*If this obvious fact had been borne in mind some of the discussion on the latter implement at the recent meeting at Toronto (B. A. A. S.) might have been avoided. One distinguished speaker spent his time in contesting its palæolithic nature which no one had even suggested. It is a ground axe of green slate and its neolithic character was, of course, assumed without argument by the archæologists in the section.

and more general term to be used in relation to those of yet later date.*

If, however, archæologists in America continue the use of the term "palæolithic" as descriptive of any of the implements thus far reported from the United States the word should be employed in a restricted sense and should refer merely to the form and nature of the artifact without any expressed or implied reference to its date. Even then, however, confusion is likely to arise and the illicit conclusion may be drawn that objects to which the same term is applied must be of corresponding age,—an inference which obviously would be a logical fallacy.

Strong confirmation of the doctrine which assigns all the hitherto published "palæolithic (?)" finds of North America to a much later date than that which is justly claimed for those of England is found in the comparative recency of their geological settings. With the exception of certain cases in the West no great changes in the physical geography of the country have occurred, the rivers are in the same valleys, the sea coast has undergone merely trivial alteration and lakes, the signs of geographical youth, still thickly dot the glaciated region. So in England neolithic "finds" occur in similar conditions.

But on the other hand since the days of palæolithic man vast changes have taken place in England. Rivers have changed their courses or have cut down their channels by hundreds of feet; they have even in some cases been converted into arms of the sea; England has been, once at least, an integral portion of the European continent, and the whole drainage system in some parts of the island has been radically altered. No one can doubt that changes so great in the one case and so small in the other prove beyond controversy that the beginning of the palæolithic era must be separated from our own by a time interval of which the neolithic era forms but a comparatively small fraction.

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*The term mesolith will probably be some day required for the transitional forms which will surely come to light in the progress of time between the typical palæoliths and the typical neoliths. Such a transition must have taken place and it is probable that in regions beyond the reach of the ice the more advanced patterns and styles were in some degree contemporaneous with the earlier forms and may also be of glacial date.

And where can a more rational explanation both of the changes and of the interval be found than that proposed by Prof. Geikie,—the relegation of palæolithic man to a glacial and of neolithic man to a postglacial date? On this view all difficulties vanish. The vast antiquity of human remains in Britain is explicable and the recency, by comparison, of all yet reported from North America becomes evident and intelligible.

This argument has been before the world now for many years and considering its cogency it is not a little surprising to find so distinguished an archæologist as Sir John Evans, in his address before the British Association at Toronto in September last, speaking in a manner betraying not a little confusion of mind on the subject. It is, of course, not to be expected that archæologists should also be geologists, but it is absolutely necessary in order to avoid serious error that each should be familiar with the discoveries of the other when they touch upon his own particular province. The study of early man is the most important meeting-point of the two sciences and here there should be harmony and mutual understanding. Yet we find in this address the expression "the Post-glacial or River-drift period." Now the river-drift is synonymous in England, at least in part and perhaps altogether, with the palæolithic period and consequently on the argument of Prof. Geikie must be of interglacial age. Indeed some of the very difficulties with which Sir John Evans has met and to which he has called attention in his address instantly disappear on the adoption of the theory here advocated. He dwells for instance on the immense duration of palæolithic time. He says it is proved "by the thick layer of stalagmite in Kent's cave"; "by the revolution which took place in the fauna after the latest of the cave-deposits of the palæolithic period"; by the remoteness of the commencement of the neolithic period and by the great changes in the surface configuration of the country. All this is evident, but when we consider what is now known of the vast length of neolithic time the geologist will find it a difficult task to crowd both it and palæolithic time into the postglacial era. It is simply impossible. But grant the interglacial date of palæolithic man and the imaginary difficulties melt away and time enough can be allowed for all the changes

referred to above and many others that were unnoticed in the address.

In another passage Sir John refers to the recent investigations of Mr. Reid which prove, he says, "that the well known palæolithic remains at Hoxne in Suffolk and Hitchin in Hertfordshire are of a later date than the Great Chalky Boulder clay of eastern England". He refers to this as showing the very recent date, geologically speaking, of these remains. But it must be recollected that the great chalky boulder clay is not by any means the last of the glacial deposits of England and that relics lying on it and therefore of later date may yet be interglacial. These almost certainly are so.

Furthermore in apparently attempting to establish the postglacial date of the palæoliths of England Sir John argues that some of them have been manufactured from materials that were brought into the region by the ice and derived from the boulder clay.

But admitting, as all must do, Sir John's high ability as an archæologist, we may be allowed to make the suggestion that if, as stated in the address, these relics at Hoxne, Brandon, etc., lie on the boulder-clay their makers can have had no trouble in obtaining the materials from the ground beneath their feet. Had they proved of older date the objection might have been formidable, but in the circumstances it is merely irrelevant.

It is too late to argue on this subject as if the glacial era consisted of a single ice-invasion—one and indivisible—and as if such an interval as interglacial time did not exist. Uncertain as its details still are there is no room for doubting the reality of the recessions and readvances of the ice and the distinction between "preglacial" and "interglacial," which Sir John seems to ignore, is of fundamental importance in the discussion of the problem of early man.

It is difficult to read the address without feeling that it is in substance an attempt to maintain the postglacial age of all the yet known remains of man. The expressions "post-glacial or River-drift period" and "the palæolithic remains of eastern England are of a date long posterior to that of the Great Chalky Boulder clay" can scarcely carry any other meaning. But as already remarked such an attempt in the present state

of our knowledge must be considered out of date and can only prove futile. The great length of "neolithic" time, on which Sir John has rightly laid much stress, utterly precludes success. The postglacial evolution of neolithic man to higher stages of civilization, the emergence of the bronze-culture and its gradual disappearance before that of iron, the spread of neolithic art over not merely the eastern but the western world, assuming its origin in the former, the slowness and the smallness of every advancing step induce the archæologist to claim for neolithic man all that the geologist can allow him of post-glacial time. And even this will probably prove too short.

The attempt to explain away or to invalidate the evidence that has at various times comes to light, especially in recent years, in favor of a yet greater antiquity for man than that implied by the term "interglacial" reminds one of the similar efforts made thirty years ago to refute the evidence of M. Boucher de Perthes. These Sir John holds up to well merited derision when he says:

> While one class of objectors accounts for the configuration of the flint implements from the gravels by some unknown chemical agency, by the violent and continuous gyratory action of water, by fracture resulting from pressure, by rapid cooling when hot or rapid heating when cold, and even regarded them as aberrant forms of fossil fishes, others adopted the view that the worked flints had either been introduced into the beds at a comparatively recent date or that the gravel was a mere modern alluvium.

Some of the objections that have been urged of late against the specimens that indicate the existence of man in England in days even preglacial will in time to come probably seem as irrelevant, if not as absurd, as those quoted above. The same may possibly be true of some objections against traces of early man in the western world.*

Another expression may be noted in the same address where the distinguished author expresses unwillingness to ac-

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*It may readily be admitted that in thousands of cases it is impossible to distinguish natural fracture from the handiwork of man. But setting these aside there is little doubt left after examination of a large number of specimens. The writer, many years ago, examined thousands, perhaps hundreds of thousands, of broken flints in the upper valley of the Thames, but he never found any such collection of chipped specimens as those shown him by Sir Joseph Prestwich in his collection from the plateaux of Kent.

cept certain implements of palæolithic type reported from below the great chalky boulder clay and remarks on "the archæological difficulty that man at two such remote epochs as the preglacial and the postglacial, even if the term glacial be limited to the Chalky Boulder clay, should have manufactured implements so identical in character that they cannot be distinguished apart."

Now waiving the question whether or not these implements of palæolithic age can be distinguished, this sentence is scarcely in accord with the following which occur later in the same address:

> The duration of the palæolithic period must have extended over an almost incredible length of time, for valleys some miles in width and of a depth of from 100 to 150 feet have been eroded since the deposit of the earliest implement-bearing beds.

Again we read:

> We have seen that during the migration of palæolithic man from his original home to the west of Europe the forms of the weapons and tools made from siliceous stones had become stereotyped and that during the extended period implied by the erosion of the valleys the modifications in the form of the implements were but slight.

If, then, so little modification occurred in the pattern of the implements during all the long palæolithic time there can be no difficulty arising from the close resemblance of the specimens made before and after the deposition of the chalky boulder clay.

All the difficulties, real and imaginary, that can be brought forward disappear, however, when we accept the conclusion of Prof. Geikie. Palæolithic man in England was a member of the southern mammalian fauna, lived in Britain in the interglacial period perhaps even during the presence of the ice, disappeared with the fauna to which he belonged and his place was taken, after an interval, by neolithic man, a member of another fauna with different arts and methods and doubtless coming from a different region.

We need not infer from what has been said that Britain was occupied by palæolithic man during all the interglacial periods though the evidence may some day prove this to have been the case. Still less can we infer the existence of preglacial man in the same region, though this also awaits proof,

and if proved would in no way interfere with Prof. Geikie's theory.[*] The immense length of palæolithic time and the monotonous sameness of palæolithic weapons are in perfect accord with what we must believe was an immensely slow progress from the anthropoid to the man. At the same time we must bear in mind that much of this monotony is very likely due to our lack of minute acquaintance with the remains of different periods of palæolithic time.

What has been said above regarding England is true for a large but undefined area in northwestern Europe. But outside of the glaciated region the wide gap existing in England between the eras of palæolithic and neolithic man is not obvious. The probability is that the future will reveal stages of palæolithic culture more advanced than those indicated by the surface discoveries in Britain. The French cavern deposits and others may also be quoted in this connection. Again earlier stages of neolithic culture will very likely come to light from places yet unsearched and in this way the chasm existing in the British history of man will probably be filled. But that this link will be found in Britain or in any country that was devastated by the ice at its widest extension is unlikely. The whole fauna of which palæolithic man was a single member disappeared from causes still largely unknown and a new one took its place with which came, as its most advanced member, neolithic man.[†]

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[*] The plateau implements to which attention was called a few years ago by Sir Joseph Prestwich in some of his last papers are apparently the oldest human remains yet known in England, and in spite of all the objections urged against their authenticity they may yet prove of preglacial age. The immense erosion of the Wealden district which has occurred since they were made and buried is alone sufficient proof of the immense antiquity of these "eoliths" as they have been well termed.

[†] Note.—Since this paper was written the objections against the very ancient plateau implements of Kent have been formulated by Mr. Cunnington in "Natural Science" and fully answered by Mr. Kennard (Nov., 1897, and Jan., 1898). On which side lies the greater weight each reader must decide for himself, but some of the objections strongly remind one of those which Sir John Evans has so justly criticized in the passage quoted above.

ANTHRACITE COAL IN ARIZONA.

By WILLIAM P. BLAKE, Tucson, Arizona.

Beds of graphitic anthracite coal occur in the mountains of the southeastern portion of Arizona. They crop out in considerable magnitude in the Chiricahua range of mountains near the bold summit, known as Cochise's Head, south of old camp Bowie, and about thirty miles from the Southern Pacific railroad at Teviston. The chief exposures are near Bridger's camp, at the head of Wood creek. The beds are there in close association with shales, sandstones, limestones and massive conglomerates, in regular strata, resting upon or against a crystalline gneissic and granitic foundation. The stratified formations are believed to be Carboniferous in age and the coal is presumably a member of the series but its exact relations stratigraphically have yet to be satisfactorily shown. The sequence of strata appears to be: conglomerate, limestone, sandstone (quartzyte), black silicious shale, coal, shales, plutonic dyke, gneiss. The stratified formations attain a thickness of 2,000 feet or more. The limestones are largely developed, and are generally blue and but little changed. They contain encrinites and here and there brachiopod shells, apparently Productus. Other portions of the rock have been altered to white sub-crystalline beds. There is an abundance of flint nodules and layers of flint. The strata dip northward at various angles but generally less than 45°.

The coal beds crop out in a ravine. They have not been much explored and some of the tunnels in which it is claimed that three beds were cut have caved in so as not to be accessible, but the great heaps of slaked coal and black dust at the mouths of such tunnels show that the material was found in quantity. The only accessible opening showed a thickness of glossy black graphitic anthracite over twelve feet in thickness. It reminds one of the hard graphitic anthracite of Rhode Island, but, except in selected specimens, it appears to carry more ash than the Rhode Island samples and to be even less available for fuel. It is hard to ignite. The percentage of ash is large, as will be seen from the following tabulated results of analyses made by me in the laboratory of the Arizona School of Mines:

Analysis of Arizona Anthracite.

No.	Sp. Gr.	Ash.	Combustible and water.	
1	1.49	13.20	86.80	Selected fragments.
2	1.73-1.80	30.45	69.55	
3	1.76	27.40	72.60	Slaty.
4	1.85	30.00	70.00	"
5		22.04	77.96	Black powder.

No. 1, had red ashes; No. 2, white ash; No. 3, white ash, tinged with red; No. 5, red ash. All the beds afford glossy black lustrous and shining masses, but generally in curved layers, and having a graphitic luster, except Nos. 1 and 5. No. 5 is taken out of the mine in a fine black powder.

It cannot be claimed that any of this material has much value as a fuel. It may be found useful in some metallurgical operations as a deoxidizing agent, or for lining (brasqueing) crucibles and furnaces.

The presence of such large beds of carbonaceous material is significant of a great area of Palæozoic vegetation and of shallow seas and coal-forming basis analogous to those of the Coal Measures. If, as I confidently expect, further investigation shall show that these graphitic anthracites are metamorphised coal-beds of Carboniferous age, our present ideas of the westward extension of the flora of that period will require great modification.

There are many evidences in southern Arizona of shallow seas in Palæozoic time, and of great tidal currents, and of extensive shore-lines. Coarse conglomerates of well-rounded pebbles of Palæozoic age abound in the Santa Ritas, in the Santa Catalinas, in the Babioquirari and other mountain ranges, and in the low hills of Arivaca, south of Tucson and near the boundary of Mexico.

Quartzytes—probably Cambrian—are a striking feature of some of the mountain ranges between Tucson and the gulf coast of Sonora.

CARBONIFEROUS FORMATIONS OF SOUTHWESTERN IOWA.

By Charles R. Keyes, Des Moines, Iowa.

For nearly half a century it has been known that the southwestern part of Iowa is occupied by "upper coal measures."

Singularly enough, during all of this time little more than the bare fact has been recorded. No succession of strata has been established; no subdivisions recognized. Neither has the unity of the sequence been demonstrated. All references to the formation have been in the most general terms. Only local unconnected sections have been described.

The rocks as a whole were commonly regarded to be far less important than they really are. Their maximum thickness, for example, was placed at 200 feet, whereas in reality the measurement is over five times as much.

Although from investigations prosecuted in the neighboring states of Missouri, Nebraska and Kansas it has been, of recent years, inferred that the thickness of the "upper coal measures" was much greater than the estimate given by White,* his account has long remained the only accessible information on that part of the state of Iowa. Much uncertainty has thus always existed concerning the geology of the region. This is well shown by Call's plans† of certain deep wells that were put down at Red Oak and Glenwood. The latter, for instance, which begins in the Plattsmouth limestone, is stated to pass through only 150 feet of strata belonging to the "upper coal measures." In this formation the well actually penetrates nearly four times the distance mentioned. Similar statements regarding other deep drill holes were wholly conjecture.

As the region came to be investigated many new facts began to furnish substantial data regarding the real extent and character of the formation. The prevailing notions were changed very materially. From observations made along the Missouri river Todd‡ was led to state that a very noticeable flexure existed south of the Platte river in Nebraska; and that a thickness of the "upper coal measures of at least 350 feet was demanded by the facts."

After the present geological survey of Iowa was organized much local information was obtained regarding the southwestern part of the state. For several years, however, pressing duties elsewhere prevented the general geology of the "upper

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*Geology Iowa, vol. I, p. 298, 1870.

†Proc. Iowa Acad. Sci., vol. I, pt. ii, p. 60, 1892.

‡Proc. Iowa Acad. Sci., vol. I, p. 58, 1890.

coal measures" from being considered systematically. The first important reference was in regard to the thickness, the estimate being placed at 1,200 feet.* The latest suggestion in this connection is by Norton,† who places the total thickness of the "lower" and "upper coal measures" combined, at 1,060 feet. In all of these references the plane of separation between the "upper" and "middle," or the "upper" and "lower coal measures"—the "middle" not being recognized—is understood to be that selected by White. It is not distinguishable at any other locality than the one noted by him, and is about 75 feet below the horizon now adopted for the division plane between the Des Moines and Missourian series.

As the result of investigations carried on in Missouri‡ the base of the Bethany limestone was found to be an horizon that afforded the greatest contrasts of all essential characters. It properly formed the division between the two principal series of the region. The Bethany limestone was later correlated with the Winterset limestone of Iowa. Since that time Bain§ has traced the outcrops of the formation all the way from Guthrie county, in the central part of the state, southward to the typical locality in Missouri.

The fact that the "upper coal measures" of Iowa, which are now incorporated in great part in the Missourian series, were never subdivided is due to a number of circumstances. The vertical extent and importance of the formation was not recognized; heavy accumulations of drift totally obscured the rocks; the region occupied by the strata is mainly a watershed, and hence no large streams exist to cut down to bedrock. In order to decipher the Iowa district it was necessary to approach it from some other direction than had been hitherto attempted,—from some locality in which the entire sequence had been clearly made out. This key was furnished by the work done in Missouri, and along the Missouri river. There the full succession of strata had been recently determined, and some of the formations traced into Iowa.

The subdivisions of the Missourian series, as developed in

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*Iowa Geol. Surv., vol. I, p. 15, 1893.

†Ibid., vol. VI, p. 333, 1897.

‡Missouri Geol. Sur., vol. IV, p. 82, 1894.

§Iowa Geol. Sur., vol. VIII, p. 25, 1898.

Missouri and Kansas, and as shown in section along the Missouri river between Kansas City and Omaha, are with their respective thicknesses, as follows:

		Feet.
11.	Cottonwood limestone	10
10.	Wabaunsee shales	500
9.	Forbes limestone*	25
8.	Platte shales	105
7.	Plattsmouth limestone	30
6.	Lawrence shales	265
5.	Plattsburg limestone	35
4.	Parkville shales*	75
3.	Iola limestone	30
2.	Thayer shales	50
1.	Bethany limestone	75

Of these the basal number, the Bethany limestone, is known in the central part of Iowa. Its course has been followed through Guthrie, Dallas, Madison, Clarke and Decatur counties. The shales immediately overlying are also known. Above them and to the westward limestones and shales crop out at intervals, but their relations to one another have never been made out.

On the western boundary of the state, along the Missouri river, there are known to be exposed the lower two-thirds of the Wabaunsee shales, the Forbes limestone, the Platte shales, the Plattsmouth limestone and the upper part of the Lawrence shales.

The Iola limestone, which is perhaps the most important calcareous member in southeastern Kansas, thins out completely before reaching the domains of Iowa. The limestones exposed in the belt some distance to the west of the Bethany outcrops must be referred to the Plattsburg division; the associated shales beneath to the Thayer and Parkville, and those above to the Lawrence. These doubtless follow the Plattsmouth limestone, the Platte shales, and the Forbes limestone,

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*The Forbes limestone is the thick limestone typically exposed in the top of the bluffs of the Missouri and Nodaway rivers near the town of Forbes in Holt county, Missouri. It is the highest heavy limestone in the Missourian series, until the capping Cottonwood is reached. The Parkville shales are best exposed near the station of Parkville north of Kansas City. The name is applied to all the beds lying between the Iola and Plattsburg limestones. All the other names have been used before. The formations and their principal section will be more fully considered in another place.

though their exact courses are not yet carefully located. They are inferred largely from the succession observed a short distance beyond the boundaries of the state in Missouri.

In southwestern Iowa the general dip of the strata is towards the west. On the Missouri river a lower anticline brings the Plattsmouth limestone again to view opposite Glenwood. All the area east of the river, as far as central Adams and Taylor counties. is occupied by the Webaunsee shales. One hundred feet above the base of these shales is the Nodaway coal seam, that is mined at so many points in Montgomery, Page, Adams and Taylor counties. The belt 30 to 40 miles wide, lying to the eastward and reaching to the outcrops of the Bethany limestone is evidently covered by the other formations already mentioned,—the Iola excepted. Northward from Kansas City the shales are found to become much thinner. Their thickness in central Iowa is very much less than where exposed along the Missouri river.

Lately a number of deep drill-holes have been put down in southwestern Iowa. The records of some of these are sufficiently accurate to be of much service in checking the succession and thickness of the beds composing the Missourian series.

The Cottonwood limestone and the overlying Oklahoman series are not believed to be represented within the limits of Iowa. The nearest known exposures are at Auburn, in Nemaha county, Nebraska, and 20 miles from the extreme southwest Iowa corner. A large part of the Missourian series, in Iowa, is overlain by Cretaceous rocks, which extend southward in a long tongue to within a few miles of the south boundary line of the state.

According to the most reliable estimate derived from the Missouri river section, and from a number of deep wells, the greatest thickness of the Missourian series in Iowa is a little over 1,000 feet. This is at the extreme southwest corner of the state. The same figures apply to Missouri, the thickest point being the extreme northwest corner of that state. The thickness of the "lower coal measures," or Des Moines series, in the same locality is about 400 feet.

THE PENEPLAIN.

By R. S. TARR, Ithaca, N. Y.

CONTENTS.

Reasons for the Paper:—Five years ago doubts concerning the value of the evidence of peneplains, which had previously come to my mind, were distinctly strengthened as the result of study in the highlands of New Jersey. I was, therefore, led to call in question the explanation which even then was being quite generally accepted. So widespread was the adoption of the idea that I hesitated to publish these doubts and decided to give the matter more thought. After two or three years a paper was prepared stating my objections, and sent to Prof. W. M. Davis for his consideration. It did not convince him, nor did his comments upon the paper convince me that the objections were unsound.

Nevertheless, the failure to convince Prof. Davis induced me to give the question still more study, with the result that the longer I have thought upon the matter, and the more extended my field observations have become, the stronger grows the conviction that the peneplain explanation is in error. Therefore, notwithstanding the fact that nearly all American geologists have adopted the peneplain explanation, and that no one has publicly questioned it, I have decided at last to state my objections in print.*

I have been led to this decision in the belief that it should be done. Every month, and sometimes oftener, one finds a statement concerning a newly discovered peneplain. They are being found nearly everywhere. Indeed they are announced upon the most meagre evidence, and oftentimes with no statement of evidence whatever. Frequently a new peneplain is mentioned as one might state the discovery of a delta

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*I am indebted to Prof. J. C. Branner, Prof. I. C. Russell, Prof. A. C. Gill and Mr. J. B. Woodworth for kindly reading and commenting upon this paper.

or a fossil vertebrate; and not only are single peneplains found in a given district, but oftentimes several of different ages.

It is perfectly certain that many of the so-called peneplains have been announced without any semblance of proof. But it is not against these that I write, for the author of the peneplain idea has himself urged more careful study before the announcement of a peneplain,—advice which has not been generally followed. The literature of geology is becoming overburdened with peneplains, and the geological history and geography of the past are often interpreted upon the basis of these. If any of the peneplains are well founded, their discovery and correct interpretation form an important factor in geological investigation. On the other hand, if they are wrongly interpreted, and the entire idea is incorrect, geological literature is becoming seriously confused, as it has been at times in the past, when erroneous ideas have prevailed in large measure as the result of authority. Should this be the case with the peneplain, the time has long since passed when the error should have been detected. Believing as firmly as I do that the peneplain explanation is incorrect, I feel that I should do wrong to longer delay the publication of my reasons.

At the same time, while I have a firm belief, as stated, doubts concerning the validity of this position cannot help arising, for the views that I hold seem opposed to those of the larger number of leading American geologists. I may be wrong, and the weight of authority would seem to indicate that I am. I hope that my paper will call out a discussion and that if I am wrong, the case will be proved beyond question. Even if this is the outcome of this paper, the discussion may perhaps have a salutary effect in putting a stop to the reckless announcement of unproved peneplains, and should lead all geologists to give a more careful study before they put forward the announcement.

Definition of a Peneplain.—A peneplain is "a nearly featureless plain" produced by subaerial denudation.* These are not true plains, but "nearly always possess perceptible inequalities, amounting frequently to two or three hundred

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*Davis: Am. Journ. Sci., 1889, ser. III., vol. XXXVII., p. 430.

feet."* This levelness is in spite of irregularity of rock "structure."† No extensive peneplains are known to exist at the present time in any part of the earth, but many are inferred from the crest lines of old mountains, which are believed to represent the remnants of dissected ancient peneplains, produced during some previous geographic cycle. It is this conception of a peneplain which is discussed here, and for typical illustrations the peneplains of New England and New Jersey are selected, because they have been most fully studied and discussed, and rest upon the firmest basis.

General Acceptance of the Peneplain Idea.—Few new theories have been so rapidly and uniformly accepted in this country as that of the peneplain suggested by Prof. W. M. Davis about nine years ago.‡ Indeed its acceptance has become so universal and indiscriminate that the author of the explanation has found it necessary to caution his followers against rashness of conclusion, and to call for a more careful study of specific cases.§ As in the case of most new ideas the followers have gone beyond the originator, and it is perfectly apparent that a great many of the so-called peneplains which have been described rest upon very much less secure basis than the types to which Prof. Davis has called especial attention. In this country many have evidently accepted Prof. Davis' explanation without question, and applied it to very doubtful cases.‖

Improbability of the Peneplain Explanation.—So far there has been no extensive peneplain of recent date, nor even an approximation to one, found on the earth's surface in regions of folded rocks. Yet if we may judge from the evidence adduced by the modern workers in physiographic geology, peneplains have been produced again and again at various times in the past. That is to say, during some past times there

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*Davis: Bull. Geol. Soc. Amer., 1896, vol. VII., p. 393.

†Davis: Am. Journ. Sci., 1889, ser. III., vol. XXXVII., p. 430; Proc. Boston Soc. Nat. Hist., 1889, vol. XXIV., p. 373; Nat. Geog. Monog., 1896, vol. I., p. 271.

‡Am. Journ. Sci., 1889, ser. IV., vol. XXXVII., p. 430.

§Bull. Geol. Soc. Amer., 1896, vol. VII., pp. 377-398.

‖I feel free to speak upon this point, since I have been guilty of the same error, having described as a peneplain in Texas something which may perhaps be a plain of marine denudation. See Proc. Phila. Acad. Nat. Sci., 1893, p. 317.

have been periods of sufficient land rest to allow mountain masses to be worn down to very near the base level. This means relative quiet, or fluctuations about an average level, for a sufficiently long period of time to admit of the slow process of approximate base leveling. Therefore, in accepting the peneplain theory, we need, as a fundamental assumption, to believe that during a part of the remote past, the conditions have been different from those that have prevailed in any portion of the known earth during the present and immediate past.

Few American geologists will be found who will deny the possibility of base leveling,—that, given time, the surface of the land will be leveled to the condition of a peneplain. Such a principle may readily be given a place in an ideal cycle of land development but there should be some real evidence before applying the ideal to the interpretation of existing conditions.

The wearing down of elevated mountains to those of moderate relief may be granted, and the theoretical possibility of their further reduction to the base level may also be accepted. But when the stage of maturity has been reached, the further process of down-wearing must become progressively slower. This will be so, partly because decreased relief of land diminishes the power of the agents of denudation, and partly in a more indirect manner, by furnishing to the undulating surface a capping of residual soil which protects the rock from the action of many of the agents of weathering. It seems impossible to state just what would be the curve of rapidity of denudation with diminishing altitude, but it is evident that the rate diminishes so rapidly with decreasing slope, that, before the condition of the peneplain is really reached, the rate of down wearing must become exceedingly slow.

In the summer of 1897 I spent a month among the mountains of central Maine, the larger part of the time being in the Penobscot drainage area. When I started upon the ascent of Mt. Katahdin, there had been five days of very heavy rain, so that the mountain trails were transformed to brooks, and the East Branch of the Penobscot had risen a number of feet, almost to the level of the spring freshets. The trail up the mountain led across this river, which was fed by mountain

torrents, having their source from 2,000 to 5,000 feet above the main river. The Penobscot was not even clouded with sediment. The mountain torrents and the smaller branches from the primeval forests were doing little more work of transportation than that of carrying their slight load of dissolved mineral. This period represents one of the three or four annual freshets when the greatest amount of work of destruction is done in the drainage area. But, even at such a time, the work done was marvelously slight in amount. During the remainder of the year, still less is done. Yet this is a mountainous region where denudation is certainly much more active than it would be in a more reduced area approaching the peneplain stage. At this rate how long will it take to reduce Mt. Katahdin, from its elevation of about a mile, and its neighbors, only slightly lower, to the condition of a peneplain?

During all the time necessary to reduce a hilly country to the condition of a "nearly featureless plain," time to be counted in immense ages, the land must remain nearly at one level; for if it is elevated, the task is increased, and the time needed for reduction correspondingly lengthened; if much depressed a part of the lowered region is submerged, and the work checked, or perhaps even lengthened by the deposit of a load of sediment upon it, which must be removed before further lowering can be accomplished.

The belief in the reduction of a country to the condition of a peneplain rests upon an assumption very difficult to realize, but which could be granted if the peneplain were proved to represent a real condition, and this to be the sole explanation. This assumption of immense periods of time, with relative land quiet during certain periods of the earth's history, conflicts so markedly with what we know of the present and past, both immediate and remote, that its acceptance means no less than the belief that at some periods of the past the conditions have been different from those of the present, and from those of that portion of the past whose history has been worked out by purely stratigraphic methods.

Add to this the fact that the extensive peneplains so far discovered are all of the past, and that no part of the earth reveals even an approximation to this supposed condition, and

it seems fair to call for evidence of the most convincing nature before accepting the ancient peneplains. So far as I can judge the evidence is not of this nature.

Lack of Evidence of Ancient Peneplains.[*]—Several observers, both in this country and abroad, have called attention to the fact that if a person stands upon a high hill in certain regions he looks over a vista of apparently level-topped crests, even though between the hills there are many deep valleys. This appearance has been described with especial fullness by Prof. Davis[†] and others for the New Jersey and the New England highlands. It is argued that these even-crested ridges and hills occur in regions of complex rock structure, and hence that the explanation cannot be the same as that for plateau crests capped by hard rock in a horizontal position. From this condition an ancient plain is affirmed, and the American school explains it by subaerial denudation, while the British school has advocated marine denudation.

It is true that as one stands upon an eminence and looks over the surface of the surrounding region, the hill tops in these places appear to be quite level. But it is equally true that the same appearance will be produced even where the ridges reach a quite different level. The appearance to the eye may be most deceptive. In order to see exactly what the conditions are, I have made a careful examination of the topographic sheets covering the highlands of New Jersey and Connecticut, and have constructed a series of profiles across the former regions.

In the case of New Jersey, leaving out of consideration all the valleys and all of the lower hills, there is a range of fully 500 feet in the elevation of the higher crests, and there is about the same range along the crest line of the very even-topped Kittatinny mountains. There is a difference of fully 900 feet between the crests of these two neighboring highlands. A series of nine parallel profiles from east to west in this region shows a very distinct lack of uniformity in the elevation of the upland crests, even if all the lower hills are eliminated.

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[*] It is to be understood that this refers only to the best established peneplains, not to those whose proof is most doubtful.

[†] See previous references.

A similar method was followed in Connecticut; and in each sheet where it was possible only those high hills whose elevations were especially marked by the U. S. Geological Survey were chosen, an especial effort being made to select only those hills which could be considered to be a part of the supposed ancient peneplain. On the westernmost sheet selected, the Cornwall, the range is between 1,787 and 1,215 feet. From this sheet eastward a strip five miles wide was followed; and upon the Winsted sheet, next east from the Cornwall, the range is between 1,600 and 1,160 feet; on the Granby between 1,240 and 720 feet; on the Hartford sheet the prevailing condition is lowland; on the Tollard sheet the range is between 985 and 660 feet, and on the Woodstock between 761 and 540 feet. The distance between the edges of the sheets, in an easterly direction, is 91 miles, in which space the total range of the elevation of the "peneplain" crests is 1,247 feet, while in each sheet the distance to the sea shore in the southern part of Connecticut is practically the same. Upon most of these sheets a range of several hundred feet between the most uniform of the crests may be found at places not more than a mile or two apart.

In Maine, New Hampshire, Vermont, western Massachusetts and the Adirondack region, with similar structure to that of the region above mentioned, and so near them that they must have been subjected to the same general degradation, the lack of uniformity of upland crests is very much more marked. One standing upon the crest of one of the mountains of central Maine would hardly find the evenness sufficient to give the appearance of levelness even to the eye, unless he were upon the top of a mountain rising well above the lower peaks, so that the differences in level disappear from view.

This unevenness of crests in the ancient peneplain remnant has not been overlooked by the advocates of this explanation; but to account for it two assumptions have been made. In New England there is an increasing elevation of the upland crests from south to north and from east to west, a difference which, in the section of Connecticut above considered, amounts to over 1,200 feet in 91 miles, measured east and west. Near the sea coast the hill tops, the supposed remnants

of the ancient peneplain, stand but slightly above the sea level, while in Maine, New Hampshire, Vermont and western Massachusetts, their elevation is 2,000 to 4,000 feet above the sea. This average rise is taken as evidence that the peneplain has been uplifted, and that in the uplifting it has been so tilted that it slopes at about the rate here indicated. So far as I can find out this is an assumption rendered necessary to explain the difference in elevation of the supposed peneplain; but I fail to find that there is any evidence to prove it, unless the peneplain be previously accepted as a condition covering this entire region. While near the coast there is a certain semblance of levelness, I am utterly unable to find even the appearance of uniformity in the more elevated sections of New England.

In addition to this general deviation from the level condition of the supposed ancient peneplain, there are certain peaks which rise distinctly above the average level of the surrounding crests which are supposed to be remnants of this peneplain. Of this mount Monadnock, in southern New Hampshire, is selected as typical, and the members of this class of hills have been given the name monadnock by Prof. Davis. There are innumerable smaller monadnocks scattered about in New England; and some, like Mt. Katahdin in Maine, are even higher than the type. This class of irregularity is explained by a second assumption,—that they now rise above the general level, somewhat as they did before the peneplain was uplifted, because they were residuals that had not been lowered to the peneplain level, probably either because of the greater durability of their rocks or some other accidental reason, such as greater original elevation. In this case also I am unable to find that there is any other proof that this interpretation is correct than that which comes from the necessity of such an explanation, made necessary by first accepting the existence of the peneplain.

Granting these two assumptions for the purpose of examining the evidence of a peneplain, I have taken several of the sheets of Connecticut and New Jersey, disregarding the gradual north and south rise of the crests, as well as eliminating the hills that rise well above what might be considered the average crest line, and hence which might be called monad-

nocks. Then, drawing a section on scale, I have computed the area occupied by the crests, reaching an elevation within 300 feet of one another and compared this area, which is all that is now left of the "peneplain," with that above or below the level. In each case the area occupied by the crests of this elevation is less than 25 per cent of the entire area examined, and is generally about 10 per cent. Assuming this to be the remnant of the ancient peneplain, as has been done by the advocates of the theory, and reconstructing this supposed ancient plain, by filling in the valleys and raising the lower hills, we have a peneplain constructed of which 75 to 90 per cent has been gratuitously supplied because of the moderate uniformity of crests whose total area is from 10 to 25 per cent of the whole. Moreover, this uniformity of crests has been obtained only after making use of two assumptions, and by means of them somewhat arbitrarily, disregarding those irregularities which are explained as monadnocks and the result of tilting.

As the result of these considerations, I cannot but believe that the basis upon which the peneplain theory is supported is not altogether solid. In point of fact there seems to be very little real evidence upon which to construct the ancient peneplain, and I am led to raise the query whether, even granting in its entirety the evidence claimed, we would be warranted in drawing so broad a conclusion from so small a basis of fact.

The second fundamentally important point in the peneplain explanation is the claim that we get this uniformity notwithstanding the complexity of the rock "structure." That is to say, I suppose, there is a lack of sympathy between the level-topped hills and the rock texture and position,* excepting possibly where the residual monadnock rises above the ancient plain. That the stratigraphy of the region here considered is complex, and the rocks variable in texture and attitude, is evident, but I question whether there is after all such a lack of sympathy between topography and rock structure as would

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*From Prof. Davis' paper it is evident that attitude of the rocks is considered as the main element under "structure," and I am not quite certain whether he meant to include texture under the term, as is so commonly done. Whether he did or not, the consideration of this point is warranted, since some have certainly considered structure as synonymous with both texture and attitude.

be inferred from the statement, "Not less notable than the former continuity of the dissected upland is the want of sympathy between its surface and the structure of the rock masses of which the region is composed."*

Concerning the rock texture in Connecticut and Massachusetts I know very little from direct observation; but for two seasons I worked in the type region of the highlands of New Jersey, climbing from valley to hilltop, and collecting rocks from all portions in a part of the western Highlands. While there are many low hills of hard rock, and possibly some of the higher ones composed of the less durable gneiss, there is, in that region, a very evident general sympathy between the present topography and the rock texture. Where limestone or non-resistant schist and gneiss exist, there are low hills and valleys, while the coarser and more durable gneiss quite generally makes the crests of the high hills. In other words, the apparent remnants of the New Jersey highland peneplain in Sussex county are really somewhat irregular hill tops composed of durable, coarsely crystalline gneisses that have a general uniformity of texture and power of resistance to subaerial denudation. So far as my observation goes, the conditions in Maine and Massachusetts are the same.

Hence the small portion of the so-called peneplain still existing, and the only part upon which the argument for its former greater extension can be based, namely from 10 to 25 per cent of the total area, is that in which the rocks are hard and rather uniform in durability. Therefore, although the rocks are complex in kind and position, they now stand in very general harmony with topography. To say that because of their hardness they now stand up at this level, while the remainder, being softer, has been lowered from the former condition of the peneplain, should be prefaced by proof that this minute fraction of the supposed whole, in reality represents the remnant of such a plain. Neither the area occupied by the remnants, nor the nature of their rocks, seems to bear evidence of a conclusive kind in favor of the peneplain theory.

It may be argued that one of the strongest bits of evidence in favor of the peneplain is not here considered. I refer to

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*Davis: Nat. Geog. Monog., 1896, vol. I., p. 271.

the fact that the region is a lowered mountain mass, evidently once of very rugged topography, but now much reduced and traversed by drainage lines of a somewhat mature form, the result of elevation. These facts I accept; but I believe that they admit of a much simpler explanation, which is proposed in a later part of the paper where this point can be considered more appropriately than here.

Evidence Against the Peneplain Theory.—It is difficult to find positive evidence against this explanation. In fact it would seem hardly necessary to do so, since the burden of proof should rest with the advocates of the explanation. At present it is generally accepted, not as a theory to be considered possible, but as a fact amply proved and to be accepted without question. Convincing evidence in its favor, which would place it upon a more solid foundation than that of a mere theory, I am unable to find, though I have searched carefully for it. I should like to have a statement of the evidence which gives the explanation any other rank than that of a hypothesis.

The point already dwelt upon concerning the improbability of the explanation seems to bear evidence against the peneplain. The length of time required to reduce a surface to this condition, and the necessity of assuming a moderate uniformity of level, or an oscillation about an average level during all this time, argues against the explanation. The time since the glacial period, by many believed to be represented in from 5,000 to 10,000 years, though lately multiplied several times this by some, has not been sufficient to strip off the till left by the ice upon the hillsides, nor to notably modify the very perfect form of drumlins, eskers and deltas formed when the ice was here. Yet mountains have been reduced to the condition of a plain so uniform that, from the remnants left us, one has but to climb to the hilltop to see the proof of a plain, needing only a power of imagination sufficient to fill up the valleys between the hills and thus build up the former undulating surface. When we see the slowness of denudation in a hilly country even a single peneplain seems most difficult to conceive; but when three, four, or even five successive peneplains are argued, as if it were as natural to grind down mountains to form plains as it would be to clip off the edges of these pages,

one may feel distinctly skeptical; and when this is argued in spite of the fact that the land is apparently so unstable, one may well demand that evidence of the best and most satisfactory kind be adduced. The instability of the land, both present and past, combined with the slowness of denudation even in distinctly upland regions, and its rapidly increasing slowness as these are lowered, appear to be evidence against the peneplain of such strength that only the most convincing proof that such plains have really existed can offset it.

Then the very irregularity of the surface, let us say of New England and the neighboring regions, argues against the peneplain so strongly that here also convincing proof of the peneplain should be necessary to offset this. The type feature of New England is not the peneplain remnant, but the low mountain. It is only in the lower portions, not far removed from the sea, that there is any semblance of a dissected peneplain. Much more than one-half of New England is distinctly mountainous and irregular. There are single isolated peaks, isolated groups of peaks, and entire mountain-masses. Where will one go in the White mountains to find evidence of a former plain? or where in northwestern Massachusetts and Vermont, or in the Adirondacks? Last summer I stood upon the crests of several of the higher peaks of Maine and looked in vain for any series of peaks that even to the eye appeared uniform in level. The region is essentially that of mature mountains somewhat roughened by recent elevation. Less markedly is the same true of the coast of Maine. Mt. Desert, Blue hill and many other peaks in that neighborhood contrast very strongly with their neighbors, some of which are half as high, others a quarter, and still others mere low hills or even reefs in the sea. A model of New England large enough to really show the differences in elevation would reveal a very irregular surface, not merely where incised by valleys cut during the Tertiary uplift, but among those uplands which should represent the ancient peneplain. Unless the evidence of the New England peneplain is of the very strongest kind, this irregularity would seem to stand forth in positive testimony against the belief in the former reduction of this region to anything approaching a plain. To attempt to account for this by exceptional conditions seems an admission of a weakness in the explanation.

So-called monadnocks appeal to me as proof against the peneplain theory. Grant for the moment the destruction of a mountainous surface to the condition of a plain under subaerial denudation, and this reduction must certainly call for a very great lapse of time. During such reduction it may be admitted that the soft rock will be much more reduced than the harder ones, and that the latter may stand well above the general level as residuals; but are the monadnock rocks essentially harder than the other hilltop rocks of the neighborhood? I know of no evidence that has been made public that Mts. Monadnock and Washington are made of harder rock than many of the much lower hills within a radius of twenty miles from them. I know of no proof that they are more resistant than the Blue hills near Boston, nor that these are harder than the lower granite hills of Essex county, Massachusetts, a few miles away. Is the rock of Mt. Washington more durable than that of Essex county, Massachusetts, or the rock of Mt. Katahdin or Blue hill, in Maine, harder than that of scores of lower hills not far away? I believe that I am correct in saying that there are no very distinct differences between the rocks of the monadnocks and the lower hills, in point of durability, while there is a difference in elevation of more than a mile. and, even in short distances, of 2,000 or 3,000 feet. In some of these cases it is certain that the rocks of low and high hills are not markedly different.

Without the existence of very notable differences in power of resistance, is it probable that a hill would stand several thousand feet above a plain which stretched all around its base, and which has been reduced to this condition by the slow process of subaerial denudation? After the region surrounding the monadnock had been reduced to the condition of a low, undulating hilly country, all the time required to plane it down to the condition of a peneplain has not been able to reduce the elevation of the higher, and hence more rapidly destroyed part, to approximately the same level!

It must be confessed that this opposing evidence is based purely upon my own ability to conceive of the processes involved. In so far as this power of conception is strong or weak, this part of the argument is good or bad. I would put it forward with more hesitation if there did not appear to be

good evidence that the rate of denudation is exceedingly slow in a forest covered country, and that the land is and has been far from stable, when long periods of time have been involved.

Alternate Hypotheses.—Two hypotheses have been suggested to explain the facts considered above: (1) that of marine denudation; (2) that of subaerial denudation. Although American geologists in general consider marine denudation possible only in rather restricted areas, this hypothesis is certainly not an improbability. So, also, subaerial denudation, if continued long enough, with land level maintained somewhat uniformly throughout, would undoubtedly reduce any area to a level condition, though the places most likely to be so reduced are those near the sea, or those in which the rocks are soft, or the elevation slight. The possibility of these two causes for reduction is not questioned, although the probability of general reduction by such causes is called in question. This doubt is still further strengthened by the belief that the evidence of ancient peneplains, upon which the entire argument of former base-leveling is founded, is far from convincing.

Summarizing this evidence it seems that the ancient plain is constructed upon the basis of the existence of moderately uniform hill crests, whose total area is not more than 10 to 25 per cent of the entire area. Even among these, the hill tops reach to considerably different elevations. Of the remaining 75 to 90 per cent the greater part is sunk below this upland level. The hill tops are mainly of hard rock, while the valleys are mainly located in the areas of less resistant beds, and the streams are, in general, in quite close accord with the rock structure. There are, moreover, numerous localized elevations, called monadnocks, reaching well above the upland level: and, in the western and northern portions of New England, at no very great distance from the coast, the region is elevated and very irregular and mountainous, as for instance in Maine, the White mountains, Green mountains, Berkshire hills and Adirondacks. These greater elevations do not correspond with marked differences in rock structure. The advocates of the peneplain admit past irregularity, in the form of monadnocks rising above the ancient peneplain, and they also admit present irregularity in a marked degree, but ex-

plain it by one of three conditions, either post-peneplain denudation, or ancient irregularities upon this peneplain surface, or differential elevation of the peneplain since its formation.

In the present condition of New England and New Jersey, I am unable to see any evidence that the region was ever reduced further than the condition of full maturity of topography,—that is, a region of hills and valleys of considerable variety, and, away from the sea shore, of rounded but considerably elevated mountains. That this mature mountain region has been subjected to later elevation, which has rejuvenated the rivers, seems certain. According to this, the present New England topography is mainly one of reduced mountains, lowered to the stage of full maturity, then elevated and made more rugged. By this explanation it is held that the region was never reduced to the peneplain stage, but has always been, as it still is, a mountainous section, though once less mountainous than now, because of the recent uplift.

So far as I can see, the facts in the field are in fuller harmony with this explanation than with that of the peneplain. The present marked irregularity of surface is explained without other assumption than that certain places were formerly, as now, either high or low, as they would naturally be in a region of mature mountains. It does away with the necessity of assuming long periods of time during which the land remained at approximately one level. To reduce a mountainous region to the stage of maturity is an easy task compared with the reduction of a mature mountain region to a peneplain. It would be impossible to state what the ratio of time is, but it is certain that to lower a mature mountain to a peneplain must take many times as long as to reduce a mountainous area to that of maturity. Moreover, much more variation in elevation is possible under the explanation here proposed than under that of the peneplain. While the mountains were being lowered to the stage of maturity, there might be very much fluctuation of level without marked interference with the continuation of the process of production of mature forms. Besides this, while there are no existing peneplains, there are at present many regions of reduced mountains approaching the stage of maturity—witness the very regions under consideration.

It may be argued that the number of hills reaching to a moderately uniform elevation which are found in southeastern New England, and in New Jersey, cannot be accounted for by this hypothesis. When we take into account their present irregularity of surface, this asserted uniformity does not appear so marked. Upon my mind the impression of irregularity is produced much more strongly than that of regularity, particularly when the monadnocks and higher irregularities of the northern and western part of New England are included. It is true that near the coast the uniformity is more marked than in the interior; but here, of course, the mountains would have been more lowered than in the interior, and, in the coastal region, there may well have been an approach toward the condition of a local peneplain. Yet, when we consider such isolated elevations as that of the Blue hills, near Boston, and the ruggedness of the Maine coast and of Nova Scotia, as well as of the region farther north in Labrador, even here, where the peneplain condition should have been most fully reached, the regularity of level can be urged only when numerous local exceptions are eliminated.

However, it is necessary, if this proposed hypothesis is to be accepted, to account for even the measure of uniformity that exists, even though it is really less marked than some believe. In the reduction of a mountain mass toward base level, long before the peneplain stage is reached it seems certain that there would be a uniformity of level among the mountain crests fully as marked as that now found in New England, and that this uniformity would naturally be greater near the sea, where development would have been most advanced.

Given a mountain region of marked irregularity, such as New England must have been during the Paleozoic, the rocks from place to place varied greatly in hardness and in attitude, while the peaks in different sections naturally reached to very different altitudes. If we should select from these, two neighboring peaks or ridges of approximately the same texture attitude, and altitude, it would follow that, since they were exposed to the same climatic conditions, their downwearing toward base level would be continued at about the same rate, as a general proposition, though, of course, there might, in any selected place, be accidents of variations which would in-

terfere. This rate of denudation among these neighbors would at first be rapid; for, in the inception of the work, the elevation was great, the slope steep, and the rocks were exposed to strong winds and powerful frost action, while they were not protected by trees. The rate of downwearing, as we see upon similar peaks in the higher mountains of the present, would have been much more rapid than at any later stage, decreasing in rapidity as they were lowered; though still being worn down rapidly until the zone of the timber line was reached. Then conditions of an entirely new kind would have been introduced, and, from that line downward, the rate of denudation of the peaks would greatly decrease, partly because of the lessened slope, but chiefly because of the protection of the forest, which holds the disintegrated pieces in place, and helps make a protection of residual soil. As the forest covering became greater, and the slope less, the soil covering would become deeper, and the rocks more and more protected, until denudation had become exceedingly slow. These two peaks, starting at the same level, having the same kind of rock throughout, and exposed to the same conditions, would reach this stage of development (namely their crests at approximately the timber line), at about the same time; and, as their crests sank lower below this level, the peaks would still stand at about the same elevation. In an extensive mountainous region there may have been a number of such cases.

But there would not be many such peaks of the same hight or so similar that they would be reduced at nearly the same rate. Some would be of easily denuded rock, and, in time, these would be very much lowered, while the harder ones stood well above the base level. There would at first be very marked ruggedness, partly the result of difference in original elevation, and partly the result of the effects of subaerial denudation upon the much elevated and differentiated surfaces. One peak, perhaps of slightly less durable rock than a neighbor, would be lowered at a very much more rapid rate than its neighbor. But there would come a time when this difference in rapidity would be very much diminished, even if the rock of the two peaks were quite different. This time would come when the zone of trees was reached; and

the difference in rate of downwearing would even more rapidly diminish as soon as a soil covering became possible. In the meantime, a higher or more durable neighbor might still be sinking more rapidly, and, in time, might almost catch up with a more favorably situated and lower peak. The curves of the rate of denudation in the two cases would approach and finally almost coincide; and, unless the rock differences were marked, the two peaks would proceed to be lowered at about the same rate. If the rock differences were very marked, there would be no exact approach; but, according to this view of the method of denudation, even though there was originally a marked difference in altitude, all peaks whose rocks were approximately the same in power of resistance would in time approach each other in altitude, the one originally higher catching up with the other whose rate of lowering was becoming rapidly diminished because of decreased elevation. It must be granted that in such a mountainous country as that of New England down below the surface there are extensive beds of rock of approximately the same hardness. That this is so is proved by the abundance of durable gneiss and granite in most low mountainous areas, as for instance in New England and New Jersey.

By this there would be a beveling of the hill tops, the highest area of beveling being that part of the tree zone in which, because of lessened slope, the rock was protected by trees and by a residual soil blanket. Down to this zone denudation would be relatively rapid, below it much slower, and increasingly slower as the beveling continued still further. In a mature mountain region so developed there would be some peaks not yet lowered to this area, and there would be great valleys depressed below it. But would it be incorrect to assume that in a given area where most lowered, from 10 to 25 per cent of the reduced mountain tops would probably have reached a fair uniformity of level? This beveling of the hill tops would be very much further advanced near the coast than in the interior, thus coinciding with the conditions found in New England.

According to this view, by the time maturity of topographic form has been reached, there will be a beveling of hill tops where the harder gneissic and granitic rock exists, the stream

valleys standing near the base level and hills of softer strata standing at levels still lower than those in which the rock is harder. Areas originally distinctly higher or harder than usual, or more unfavorably situated, may be less lowered and more irregular than the surrounding region, though still engaged in an approach to this lower level. A well matured surface would then present three intergrading stages in different places and under different conditions. (1) Local base levels in the valleys; (2) general well matured topography with many hills reaching to approximately the same general level, but with some distinct and many indistinct "monadnocks"; (3) exceptional and localized *early* maturity, found particularly in the interior. The further the topographic development had gone toward old age, the greater would be the extent of the first two areas. Can any evidence be adduced to show that New England has ever advanced further in development than this stage?

Granting such a reduction, with many hills of hard rock standing at a moderately regular level if an elevation succeeds, while the valleys will be deepened and the hills lowered, the rate of lowering of the hills will be so nearly uniform, since the climate and rock are so nearly alike, that the measure of uniformity of upland level will in part be maintained.

Conclusion—The questions raised in this paper are not against the great importance of subaerial denudation, which few American geologists are inclined to underestimate. The stamp of the genius of Powell, Gilbert, Davis and others is too plainly marked upon the minds of American geologists for any underestimation of the importance of this. The question I raise is whether far too much importance has not been assigned to this great work. The facts and assumptions upon which the peneplain theory is based are also called in question, and an attempt is made to show that all the phenomena believed to indicate the existence of peneplains in New England and New Jersey can best be explained without assuming the reduction of a high mountainous country to the condition of old age, a condition now nowhere found on the earth.

The alternate hypothesis of beveling down to mature form is advanced. This hypothesis requires no long periods of relative quiet, and no assumptions to explain the irregularities of

the surface, which, by the peneplain theory, call for special causes whose operation is apparently not otherwise proved, and which, in part, appear to be hardly probable. The theory of the peneplain calls for a "nearly featureless plain"; the alternate hypothesis of beveling calls merely for a greatly reduced, but still markedly irregular surface. To some the difference between these two hypotheses may seem slight, but really it is great; for, after the rounded features of maturity are reached, the advance to such old age topographic features as the peneplain demands, calls for immense periods of time with land standing at nearly the same level, conditions which seem at variance with the facts which geologists have been collecting in the last half century.

STUDIES ON AN INTERESTING HORNBLENDE OCCURRING IN A HORNBLENDE GABBRO, FROM PAVONE, NEAR IVREA, PIEDMONT, ITALY.

By Frank R. Van Horn, M. S., Ph. D., Case School of Applied Science,
Cleveland, Ohio.

This hornblende gabbro* consists of the following minerals with an approximate estimate of their percentages: plagioclase, mostly bytownite, 33, hornblende 27, diallage and hypersthene 25, magnetite and spinel 15. After the plagioclase, the brown hornblende is the most important mineral of the rock and makes up about 27 per cent. of the same. It generally occurs in irregularly shaped but compact patches, and only occasionally has an approximately idiomorphic form in the prismatic zone. This is somewhat peculiar as it is one of the most basic constituents of the rock, but the lack of idiomorphism may perhaps be explained by the high percentage of alkalies which this mineral contains. Ægirine, arfvedsonite and other minerals with a large percentage of alkalies which occur in elaeolite syenytes show

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*For further description of the rocks of this region, see Tschermak's Mineral. und Petrogr. Mitth., Bd. XVII, Heft. 5; Frank R. VanHorn, "Petrographische Untersuchungen über die Noritischen Gesteine der Umgebung von Ivrea in Oberitalien."

an analogous behavior. The prismatic cleavage of the hornblende is very good, and the cleavage faces possess a splendent luster so that the angle could be determined with the goniometer. Measurements on twenty-five different pieces gave an average value of 124° 18′. Twins after the orthopinacoid (100) occur at times. The mineral has a grayish brown streak and a specific gravity of 3.217 to 3.222 at a temperature of 17° C. At red heat it does not melt, but before the blowpipe at white heat it melts to a brown glass which is soluble in hydrochloric acid.

The pleochroism is very strong:

a =light yellow (Radde, International Color Scale, orange 4, u),
b =brown with tinge of red (Radde, vermillion 3, about i-k),
c=brown with tinge of yellow (Radde, orange 4, about i-k).

The absorption is **b** > **c** > **a**. The extinction angle was determined on the prismatic cleavage faces. Twenty-five measurements gave an average of 11° 5′. In sections parallel to (010) the extinction angle was found to be 14° 30′ to 15° 30′ **c** : *c*. This hornblende was carefully isolated from the rock by means of the Klein solution (cadmium borotungstate), and this was attended with great difficulty owing to the nearness of the specific gravity of the hornblende to that of the diallage also occurring in the rock. The pure mineral was analyzed by Dr. M. Dittrich of Heidelberg, Germany. He determined the water not only indirectly by means of ignition but also according to the direct method proposed by Sipöcz and Ludwig.* The determination of ferrous iron was carried out according to the method suggested by Dölter.† The result of the analysis is found under I, while for comparison, three other analyses are given. Under II is found a hornblende from Vesuvius analyzed by Rammelsberg, under III is a second hornblende from Vesuvius which Berwerth analyzed, and finally, under IV is found the analysis of a hornblende from the island of Jan Mayen by Scharizer.

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*E. Ludwig und L. Sipöcz, Tschermak's Mitth., 1895, 211 and Zeitschrift für Anal. Chem., 17, 206.

†C. Dölter, Zur Kenntniss der Chem. Zus. des Augits, Tschermak's Mitth., 1877, 281, and 1880, 100.

	I.	II.	III.	IV.
SiO_2..........	39.58	39.92	39.80	39 17
TiO_2........	Trace	....	.....	.....
Al_2O_3.......	14.91	14.10	14.28	14.37
Fe_2O_3......	4.01	6.00	2.56 .	12.42
FeO	10.67	11.03	19.02	5.86
MnO.......	Trace	0.30	.....	1.51
Mgo........	13.06	10.72	9.10	10.52
CaO........	11.76	12.62	10.73	11.18
Na_2O.......	2.87	0.55	1.79	2.48
K_2O........	0.62	3.37	2.85	2.01
H_2O........	2.79	0.37	1.42	0.39
	100.27	98.98	101.55	99.91
Sp. G. ...	3.217-3.222	3.282	3.298	3.33

In the analysis the direct determination of water is given. Water as ignition was 1.29. The first glance at the analysis shows us that our hornblende is a very basic one with a high percentage of alumina and an amount of alkalies which is quite rare for hornblendes occurring in gabbroid-noritic rocks. In the Jan Mayen mineral ferric iron predominates, while the Pavone hornblende has mostly ferrous iron. The hornblende analysis most nearly resembling ours is the one from Mt. Vesuvius given under II. It is certain that in the analysis of many hornblendes, not enough attention has been paid to the determination of the water which, I think, plays an important role in the composition of the more basic members of this family. Many determine this only by ignition which always gives too low a result, as part of the oxygen is used for the oxidation of the ferrous iron. The direct determination according to the Sipöcz-Ludwig method is apt to give a result somewhat high. However, in my analysis a large number of "blind trials" were made before the analysis itself was carried out and the percentage of water here is, I think, very little, if any, higher than it should be. If we compute Fe_2O_3 as Al_2O_3, FeO as MgO, and K_2O as Na_2O, we can make the following calculation of our analysis:

	I.	II. I on basis of 100.	III. Molecular proportions.	IV. Simplification of III.	V. Molecular proportions taken.	VI. Proportions in whole numbers.
SiO_2..........	39.473	42.162	700	12.50	12.50	50
Al_2O_3, (Fe_2O_3)	17.418	18.604	182	3.25	3.25	13
MgO, (FeO)..	18.935	20.225	505	9.01	9.00	36
CaO..........	11.728	12.527	223	3.98	4.00	16
Na_2O, (K_2O).	3.285	3.509	56	1.00	1.00	4
H_2O......	2.782	2.971	165	2.94	3.00	12

We therefore obtain the following proportions: $12H_2O$: $4Na_2O$: $16CaO$: $36MgO$: $13Al_2O_3$: $50SiO_2$: which written as a formula gives $H_{24}\ (Na, K)_8\ Ca_{16}\ (Mg, Fe)_{36}\ (Al, Fe)_{26}\ Si_{50}\ O_{207}$. This on calculation gives the following per cents. for its theoretical composition:

	Calculated.	Found.	Difference.
SiO_2	42.099	42.162	+ 0.063
$Al_2O_3,(Fe_2O_3)$	18.607	18.604	− 0.003
MgO, (FeO).	20.207	20.225	+ 0.018
CaO	12.573	12.527	− 0.048
Na_2O, (K_2O)	3.480	3.509	+ 0.029
H_2O	3.031	2.971	− 0.060
	99.997	99.998	

We see from the formula that this hornblende is very near an orthosilicate, and that it is in reality slightly more basic than such a one. This is seen more clearly if we simplify still more the formula above given by calculating Fe_2O_3 as Al_2O_3, FeO and CaO as MgO, $Na_2\ O$ and K_2O as H_2O. We then obtain the following:

	I.	II. I on basis of 100.	III. Molecular proportions.	IV. Simplification of III.	V. Molecular proportions taken.
SiO_2	39.473	44.881	748	3.85	4
Al_2O_3, (Fe_2O_3)	17.418	19.804	194	1.00	1
MgO, (FeO, CaO)	27.312	31.054	776	4.00	4
$H_2O,(Na_2O,K_2O)$	3.747	4.260	236	1.21	1
	87.950	99.999			

We have then H_2O: $4MgO$: Al_2O_3: $4SiO_2$ or $(H, K, Na)_2\ (Mg, Fe, Ca)_4\ (Al, Fe)_2\ Si_4O_{16}$ from which is easily seen that the proportions are those of an orthosilicate. If we calculate the theoretical composition of this formula we obtain as follows:

	Calculated.	Found.	Difference.
SiO_2	46.15	44.48	− 1.27
$Al_2O_3,(Fe_2O_3)$	19.61	19.80	+ 0.19
$MgO,(FeO,CaO)$.	30.76	31.05	+ 0.29
$H_2O,(Na_2O,K_2O)$	3.46	4.26	+ 0.80
	99.98	99.99	

Since the differences are so very slight it seems best, and certainly much more simple, that we accept this abbreviated

formula as the probable one of the hornblende from Pavone, which would give us the following general formula.

$$R^{I}_{2}\ R^{II}_{4}\ R^{III}_{2}\ Si_4O_{16}$$

or, writing monovalent elements as divalent ones, we get

$$R^{II}_{5}\ R^{III}_{2}\ Si_4O_{16}$$

and consider it as an orthosilicate. Scharizer* in 1884 in his article entitled "Die basaltische Hornblende von Jan Mayen nebst Bemerkungen über die Constitution der thonerdehaltigen Amphibole," concluded that there was an orthosilicate molecule with the formula $(R^{I}_{2}, R^{II})_3\ (Al, Fe)_2\ Si_3O_{12}$, which entered largely into the composition of certain basic hornblendes. This molecule he called syntagmatite, using a name previously given by Breithaupt to certain hornblendes from Mt. Vesuvius or Monte Somma. The hornblende from Jan Mayen, the analysis of which is given above, coincides very nearly with the syntagmatite formula. Scharizer regards the aluminous amphiboles as composed of mixtures of the metasilicate molecule $Ca\ (Mg, Fe)_3\ Si_4O_{12}$ (actinolite), and the orthosilicate molecule $(R^{I}_{2}, R^{II})_3\ (Al, Fe)_2\ Si_3O_{12}$ (syntagmatite). There is little reason why we should not accept this view, even as, in the feldspar and scapolite groups, we have accepted the theory that salts of different acids such as polysilicates and orthosilicates could form isomorphous mixtures with each other. The Pavone hornblende is an orthosilicate like syntagmatite but seems to have a more complex formula than the latter. We may consider it as Syntagmatite plus a normal orthosilicate molecule, as follows:

$$R^{II}_{5}\ R^{III}_{2}\ Si_4O_{16} = R^{II}_{3}\ R^{III}_{2}\ Si_3\ O_{12} + R^{II}_{2}\ SiO_4.$$

(Pavone hornblende) (Syntagmatite)

In the past we have been too careless in making our hornblende analyses, especially in the water determination, but this analysis of the Pavone hornblende as well as those of Scharizer, Berwerth and others makes it seem very probable that an orthosilicate molecule enters largely into the composition of the aluminous amphiboles.

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*R. Scharizer, Neues Jahrbuch, 1884, II, 142.

[European and American Glacial Geology Compared. V.]

BEN NEVIS, THE LAST STRONGHOLD OF THE BRITISH ICE-SHEET.

By WARREN UPHAM, St. Paul, Minn.

Sailing down loch Lochy and the river of the same name on the Caledonian Canal steamer "Gairlochy," in the beautifully clear and welcomely warm day of June 29th, last summer, we had southward a most inspiring view of Ben Nevis and its great companion mountains extending east to loch Treig. The upper part of these mountains then bore, as I counted, about fifty patches and more extensive tracts of snow, up to a third of a mile in length, lying on their mostly shaded northern slopes and in their ravines, the remnants of the abundant and deeply drifted snows of the previous winter, reinforced in some degree by the frequent later snowfalls of the spring and early summer.

Here the Scottish Highlands attain their greatest altitude, the highest point of the somewhat plateau-like top of Ben Nevis being 4,406 feet above the sea. Until this honor was determined by exact leveling, it had been generally supposed to belong to Ben Macdhui* (or Muich Dhui), which has a similarly massive top, 4,296 feet above the sea, situated fifty miles northeast of Ben Nevis. On both these mountains snow drifts usually linger until late in summer, and during many years are not wholly melted. Like the summer snow arch spanning the brooklet of its melting in Tuckerman's ravine, on Mt. Washington, in New Hampshire, these lingering snowbanks on the highest Scottish mountains show that moderate climatic changes might bring the beginning of snow and ice accumulation again upon these lands. Probably the early Quaternary continental uplifts of North America and of the west side of the Old World, to the extent of 3,000 to 5,000 feet above their present altitude, which are known by former river valleys submerged to these depths by the sea on the eastern and western coasts of the United States and Canada, in the fjords of Norway, in the bay of Biscay, on the Portuguese coast, and on the west coast of Africa south of the equator, were sufficient to cause the glaciation of the great

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*Anglicized, in accordance with its pronounciation, this name would be spelled McDewey.

north temperate and frigid regions of our continent and Europe which are drift-covered.

An observatory for weather observations was established on the summit of Ben Nevis in 1883, and hourly records during both day and night are taken there for comparison with a meteorological station close to the sea level at Fort William, only five miles distant to the west. The mean annual precipitation of rain and snow (the latter being reduced to its equivalent of rain) recorded during the first ten years at the Ben Nevis observatory was 142.34 inches, being the greatest known at any locality in Scotland; while for the same period at Fort William it was 75.79 inches. In comparing this rainfall, as Jamieson has done,* with that of other parts of Scotland, we find its eastern half to receive much less rainfall yearly, decreasing eastward from 40 to 25 inches; but in western Scotland, from Gare loch north-northwest to the Isle of Skye, a wide belt of the Highlands has 80 inches and upward of mean yearly rainfall.

Upon this tract of very abundant rainfall and snowfall, probably the earliest part of the Scottish ice-sheet in the Glacial period was amassed. It gradually filled the valleys and glens, and finally overtopped the mountains, excepting apparently a few of the highest summits. Meanwhile the ice accumulation extended far outward over the whole country, into confluence with the ice-sheet of Ireland, the ice-fields of the Southern Uplands, of the mountains in the English Lake District, and of Wales; and, on the east, it became confluent with the great ice-sheet deploying from the mountainous Scandinavian plateau on the wide low plain that is now covered by the shallow North Sea.

When the Glacial period ended, the confluent European ice-sheet in its departure doubtless became again divided, as during the early states of growth, into separate parts flowing outward from the great central tracts of maximum snowfall. The courses of glacial striæ, and of the dispersal of drift, give clear evidence of the areas which thus preserved the latest remnants of the formerly confluent icefields. In the British Isles, probably the last remnant to melt away was in western Scotland, lingering somewhat longer, on account of the alti-

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*Quart. Jour. Geol. Soc., XLVIII (1892), 5-28.

tude of the mountains and the very plentiful snowfall, than any part of the icefields of Ireland,, Wales, and England. Many recessional moraines of that closing stage of the British glaciation in the neighborhood of Ben Nevis were observed and mapped by me in Glen Roy, in the Spean and Lochy valleys, and in Glen Nevis, along a distance of about twenty miles from northeast to southwest.

The day of my ascent of Ben Nevis, June 30th, had so fair a morning that it beguiled me to delay until in the later part of the day I entered clouds and a rainstorm on the summit. Instead of having the wide outlook that was thus prevented, I found in the observatory library Sir Archibald Geikie's very instructive book, "The Scenery of Scotland," in which I read there an hour, taking notes on the Great Glen, the Parallel Roads, Ben Nevis, etc. From the bridle path, in ascending, I had noted four small moraines stretching across Glen Nevis at the southwestern base of the mountain, between three and five miles from Fort William. On my return I noted four or five other little moraines, crossing the lower part of Glen Nevis, on the farms at the foot of the bridle path.

Next to the north, a larger moraine extends a miles eastward from the Nevis bridge; and between one and two miles farther north a belt of such morainic drift knolls and small ridges, 10 to 30 feet high, strown with many boulders, runs from the northwest base of Ben Nevis west and northwest across the Lochy valley to Banavie and the adjoining hills.

Thence passing on July 1st, and again on the 3rd, by the railway northeast to Roy Bridge station, I counted and approximately mapped nine narrow moraines, at intervals varying from a quarter of a mile to one mile apart, in the distance of about six miles from the new Inverlochy castle to the most northeastern one noted, which crosses the Spean valley from north to south and southeast about a third of a mile east of Spean Bridge station. These moraines vary from a few rods to an eighth of a mile in width, and reach one to two miles across the valley which is followed by the railway. Their hillocks and ridges of bouldery drift rise only 10 to 20 feet above the smooth and cultivated intervening parts of the valley. The moraine noted close east of Spean Bridge appears to mark the place of the ice-front when it was the barrier of

the latest stage of Lake Roy, with outflow at the col east of loch Laggan.

In going up Glen Roy, I found moraine drift amassed east of the south part of Bohuntine hill, and more remarkably about a mile further north, adjoining the northeastern curving base of this hill, with stratified overwash drift, which was deposited in lake Roy, extending with decreasing hight from the last mentioned moraine for a half mile or more up the glen. From the sharp bend of the highway on this prominent moraine, the best view of the Parallel Roads, running along the higher mountain sides, is obtained.

Again, about two miles and a half farther up this narrow valley, another definite moraine was found, nearly blocking the glen, but cut in a deep gap by the stream, which flows some 200 feet below the crest of the moraine.

But the most interesting morainic accumulation (as Prestwich regarded it to be) occurs between two and three miles farther up Glen Roy, extending about three-fourths of a mile from north to south across the mouth of the river Turret, tributary to the Roy from the northwest. This massive drift accumulation rising 75 to 100 feet above the rivers Turret, and Roy, which I think to be a moraine amassed in the edge of lake Roy at its highest stage, consists largely of stratified drift, varying from laminated silt to coarse gravel with angular boulders up to three or four feet in diameter. Jamieson thinks it a delta of the Turret, but this seems inconsistent with the open lower valley of that stream before it intersects this drift deposit. More in harmony with the other observations of moraines before noted, I believe Prestwich's view the true one, after reading Jamieson's discussion of it and examining the locality.

The reference of the Parallel Roads to glacial lakes barred by the waning Scottish ice-sheet, which Jamieson has presented in his latest paper on this subject, before cited, instead of his earlier explanation by barriers of local valley glaciers, seems to be supported by the series of about twenty retreatal moraines which have been here described in the order in which they were observed, opposite to the chronologic order of their formation by this receding remnant of the ice-sheet. Step by step, as shown by these moraines, the vanquished

ice-sheet withdrew until its last stronghold, probably the latest in Britain, was this highest mountain of Scotland.

The difficulty of supposing valley glaciers of later origin to have obstructed the Great Glen and Glens Spean and Roy is well stated by Jamieson, showing rightly, as I think, that the Parallel Roads are a record of the end of the general glaciation of Scotland, rather than of a later stage or epoch of renewed ice accumulation. Similar difficulties seem to me to oppose the view of Prof. J. B. Tyrrell, who has supposed an ice-sheet first amassed on the Cordilleran area of North America, then waning, and succeeded by a chiefly later ice-sheet on the Keewatin region of the interior of this continent, which in its turn decreased, to be followed in time by the chief accumulation of a Laurentide or Labradorean ice-sheet.* On the other hand, my interpretation of our glacial striæ and drift transportation, with frequent changes of the glacial boundaries and overlapping of the drift deposits, refers the glaciation of these three great regions of North America, like that of the British Isles and continental Europe, to the same time, with confluence during the greater part of the Glacial period, and with later division into separate icefields, corresponding to the great areas of glacial radiation, when the previously united and continuous North American ice-sheet melted away.

In connection with the moraines of Glen Roy and the lower part of the Spean valley, brief mention ought to be made of the three very admirably developed moraines which extend eastward from the east end of the Creag Dhubh mountain mass south of the Glen Glaster col. These moraines, formed during the Glaster stage of lake Roy, reach four miles or more, athwart the Spean valley six to eight miles east of the mouth of Glen Roy. The more southern and western of the three moraines curves in a semicircle across the rather level moor east of Tulloch station, and its northern part runs along the northern foot-slope of the great mountain east of loch Treig, there being represented by three or four district morainal lines on the steep rock slope.

Another paper, for which I took plentiful notes, might be written on the very interesting kames and kame plateaus which are admirably displayed along an extent of nearly two

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*Journal of Geology, IV, 811-815, Oct.-Nov., 1896; VI, 147-160, with maps, Feb.-March, 1898.

miles between the mouth of loch Treig and Tulloch. At this locality Louis Agassiz, in his visit to the Parallel Roads in 1840, expressed his delight and enthusiasm in finding these sure records of glacial action, unsurpassed, as he affirmed, by any place in the Alps. While lake Roy in its latest and most extended stage was forming the lowest of the Roads, the only one found in the Spean valley, the site of loch Treig was occupied by ice, as is known by the absence of that Road on the mountain slopes inclosing the loch.

The absence of trees or even bushes from the greater part of the country here described made it very easy to trace the moraines, as on the western prairies and plains of the northern United States. As was said at the close of my second paper in this series, again it may be remarked here that probably many such small retreatal moraines will be found in the valleys of the White mountains of New Hampshire, and of the Green and Adirondack mountains, when the general clearing away of the forests shall favor their discovery and mapping. Probably Mts. Washington and Marcy, like Ben Nevis, were fastnesses latest relinquished by the waning glaciation of the surrounding country at the end of the Ice age.

REVIEW OF RECENT GEOLOGICAL LITERATURE.

Mineral Resources of the United States, 1896. By DAVID T. DAY. (Eighteenth Annual Report, U. S. Geol. Survey, for 1896-97; Part V, in two volumes: I. Metallic Products and Coal, pp. xii, 642; II. Nonmetallic Products, except Coal, pp. 643-1400. Washington, 1897.)

These separately indexed volumes, compiled with the aid of expert assistants, are published before the other parts of this annual report, that the statistics and discussion of the year's mineral industries and production shall be given as early as possible to those engaged in mining, quarrying, and all related industries and manufactures. For this purpose, separate brochures of many chapters, as those treating of iron and steel, building stone, clay-working, mineral paints, abrasive materials, etc., have been issued, as the printing advanced, before the completion of the whole, which was issued about May 1st of this year, as early as was consistent with accurate collection and presentation of the extensive details of the subject in its many departments.

The report on iron ores, by John Birkinbine, occupies 28 pages, showing a product of 16,005,449 tons (long tons, of 2,240 pounds), a slight increase over 1895, and nearly equal to the maximum iron ore production, which was attained in 1892. A very valuable report on iron and steel and allied industries is presented by James M. Swank, the general manager of the American Iron and Steel Association, in 90 pages. This includes statistics for long series of years in the United States and in all iron-working countries, with tables of their production, and of their exports and imports, of iron and steel and of coal and coke. A final table states the railroad mileage of all parts of the world at the end of the year 1895, the United States having 181,717 miles, Europe in total, 155,284 miles, and the entire world, 433,953 miles.

The product of gold by the United States in 1896 was the greatest ever attained, being valued at $53,088,000. It was an eighth more than in 1895, and a quarter more than in 1894. The commercial value of the silver produced was $39,655,000, showing also a considerable increase over the preceding years.

Copper production attained the value of $49,456,603, of which 59 per cent. was exported. In similar manner each branch of our mining, quarrying, clay-working, and other industries developing the geologic resources of the United States is noted in much descriptive detail, statistics, and comparison with previous years and other countries.

Among the contributors of these special reports are Charles Kirchhoff, on copper, lead, and zinc; R. L. Packard, on aluminum; John Birkinbine, on the ores of iron and manganese; Joseph Wharton, on nickel and cobalt; Edward W. Parker, on antimony, coal, coke, asphaltum, soapstone, abrasive materials, sulphur and pyrites, gypsum, salt, fluor spar and cryolite, mica, asbestos, mineral paints, and barytes; F. H. Oliphant, on petroleum and natural gas; William C. Day, on stone; Jefferson Middleton, on clay-working statistics; Heinrich Ries, on the clay-working industries, and on feldspar and quartz; Spencer B. Newberry, on Portland cement; Uriah Cummings, on rock cement; George F. Kunz, on precious stones; and Albert C. Peale, on mineral waters.

The total value of the mineral products of the United States for the year 1896 is shown as $623,717,288, being about $1,090,000 more than in 1895, and two-fifths more than in 1880.

For geologists, seeking knowledge of the mode of occurrence of valuable geologic formations and their origin (rather than the results of their working, which are of chief commercial importance), the most interesting paper of this report is by George F. Becker, on "The Witwatersrand Banket, with Notes of other Gold-bearing Puddingstones," in 32 pages, with a map. The gold ores now worked on so vast scale in the vicinity of Johannesburg and elsewhere in the Transvaal are found to be in marine gravel and sand, stretching along the former southern shores of the African continent. In the more northerly adjacent gold districts, extending into Mashonaland the gold occurs in veins, mostly in schists and granitoid rocks; and there many abandoned sites of former mining and smelting have been discovered,

indicating that region to be probably the Ophir of the ancients. Rivers flowing thence to the sea brought the gold-bearing littoral marine sands and gravels, of Paleozoic age (perhaps Devonian or Lower Carboniferous), which have yielded from $20,000,000 to $38,000,000 of gold yearly since 1891. Similar auriferous marine deposits in many other parts of the world, including Nova Scotia, North Carolina, the Black Hills, the Big Horn range, California, and Alaska, are also noted in this paper. Indeed, Dr. Becker shows that nearly all pre-Tertiary gold-bearing gravels are of such marine deposition as in the Transvaal. W. U.

Reconnaissance of the Gold Fields of Southern Alaska, with some Notes on General Geology. By GEORGE F. BECKER. (From the Eighteenth Annual Report, U. S. Geol. Survey, for 1896-97, Part III, Economic Geology, pp. 1-86, with 31 plates and 6 figures in the text. Washington, 1898.)

This report presents a great amount of detailed geologic information, mainly relating to the gold mining and gold-bearing rocks at Juneau and other localities on the southern coast of Alaska, based on observations by the author in 1895. It will be read with great interest on account of the recently discovered and wonderfully rich placer mines of the Upper Yukon district, which are the subject of the next paper. The product of gold from the Alaska-Treadwell mine in the fifteen years since it was opened, up to the end of the year 1896, was $7,028,649. Its ore in 1893 and 1894 yielded only $3.20 per ton, and the cost of its working, with daily wages from $2 up to $5, was only $1.35 per ton. This mine in 1889 to 1893 produced about two-thirds of all the gold mined in Alaska; but since 1893 its proportion has been a half to a third, the whole gold production of Alaska in 1896 being estimated, by the director of the mint, as $2,055,710. W. U.

Iowa Geological Survey. Administrative Reports. (Iowa Geol. Survey, vol. 8, pp. 9-49, plates 1-2, 1898.)

The sixth annual report of the state geologist, Samuel Calvin, gives a detailed statement of the work of the survey for 1897. This report shows that the activities of the survey have been directed toward a number of important lines of research, among which are special work on the drift and on the Carboniferous, investigations and aid in developing the natural resources of the state, collecting of mineral statistics and areal county work. During the past year areal county work has been completed in the following six counties: Dallas, by A. G. Leonard; Scott, by W. H. Norton; Decatur and Plymouth, by H. F. Bain; Delaware and Buchanan, by Samuel Calvin. It is expected that the reports on these counties will be published in the present volume (VIII) of the survey. In previous years twenty counties have been mapped and reported upon, making a total of twenty-six counties in which the work has been completed.

The report of the assistant state geologist, H. F. Bain, presents statem [illegible] work conducted in a number of counties,

one of the chief points of study being the separation of the different drift sheets.

A welcome addition to the information presented by the Iowa survey consists in a report on the mineral production of the state, the statistics for which were collected and tabulated by the secretary of the survey, Miss Nellie E. Newman. The total value of the mineral production of Iowa for 1897 was $7,446,800.42, of which nearly five-sevenths represents coal.
U. S. G.

Kalgoorlite— a new telluride mineral from Western Australia. By E. F. PITTMAN. (Records Geol. Survey, N. S. Wales, vol. 5, pt. 4, pp 203-204, Feb. 1898.)

A brief description is given of this mineral which occurs with the rich telluride deposits of Kalgoorlie in crushed and foliated quartz porphyry dykes. Among the tellurium minerals is an iron black mineral with a specific gravity of 8.791. It is massive and has a sub-conchoidal fracture. An analysis shows:

Mercury	10.86
Gold	20.72
Silver	30.98
Copper	.05
Sulphur	.13
Tellurium	37.26 (by difference).
	100.00

From this analysis $HgAu_2Ag_6Te_6$ is calculated as the empirical formula. The kalgoorlite occurs associated with pale yellow calaverite.
U. S. G.

Catalogue of the Tertiary Mollusca in the Department of Geology, British Museum (Nat. Hist.). Pt. 1. The Australian Tertiary Mollusca. By GEORGE F. HARRIS. (8vo; xxvi and 407 pp., 8 pls.; London, 1897.)

The catalogues published by the trustees of the British museum generally contain much more than their titles imply. In them will often be found some of the latest applications of the laws of evolution and the elucidation of new and important principles of morphology. Discussions of this nature have added value and weight from the intimate association of specimens and ideas, for usually curators of collections and custodians of ideas are too frequently dissociated. It is, therefore, a wise policy to engage the services of the highest talent in the preparation of the catalogues or reports on various collections or classes of organisms.

Thirteen volumes on fossil vertebrates, eight on fossil invertebrates, and three on fossil plants have already been published in this series, and Dr. Woodward states that thirty volumes more will be needed to include the remainder of the plants and *Mollusca*, the whole of the *Brachiopoda*, *Annelida*, *Arthropoda*, *Echinodermata*, and *Cœlenterata*.

The present catalogue of the "Tertiary Mollusca of Australasia" is based upon the study of large collections, especially rich in well-

preserved *Gastropoda*. Mr. Harris has thus been enabled to study the larval shells and the stages of growth with accuracy and precision. In studies of phylogenies and in the systematic classification of the *Gastropoda* the results are important. The scaphopods and lamellibranchs are also included, but owing to meager material they have afforded insufficient data for general conclusions.

Some valuable suggestions are given governing the correlations of phylogeny with chronology. Thus, a genus that has survived from early Mesozoic times, with but little modification in the later stages of its history, has had its day and settled down to a more or less fixed form. Such a genus is of little use for homotaxial purposes, though interesting phylogenetically. In the Tertiary the determination of homotaxis can best be based upon families which originated in Jurassic or Cretaceous times and reached the Eocene with strong tendencies to variation; yet, at the same time, the members should be capable of wide and rapid dispersion.

The general law is suggested that when the main features of ornament are foreshadowed in the early nepionic or brephic stage, and especially when they obtain even in the protoconch, that ornament may be regarded as of value in the determination of species. On the contrary, when the ornament does not make its appearance until the late neanic or adolescent stage, and, even in an elementary sense, is not completed until what may be regarded, by analogy, as the early mature stage, that ornament merely characterizes the individual, and is only of negative use for the purposes of classification.

As is well known, the size of the protoconch is variable, even in the offspring of a single individual, that difference being commonly attributed to carnivorous proclivities on the part of the larger specimens when in the embryonic stage. The author also notes that the size of the protoconch does not seem to have much influence in determining the size of the shell in the adult. The larger protoconch is not very often accompanied by the production of a larger adult shell than that which comes from a much smaller protoconch, that is, in the same species. There are, however, exceptions to this, and, correlatively, it may be noted that the shape of the protoconch occasionally determines the general shape of the shell.

Further interesting observations are made on the development of the *Volutidæ*, the columellar plications in *Mitra*, and the recurrence of a type of ornamentation in a species of *Cerithium*. All the genera are briefly described, and the type species is given. The notes on the species are preceded by a list of the synonymy and bibliographic references.

Some changes in the nomenclature of the genera will not meet with general endorsement, although the principles adopted are, for the most part, those approved by the best authorities. Thus, the name *Nuculana* (Link, 1807) is used instead of *Leda* (Schum., 1817) on the ground of priority. *Nuculana* however was given by Link

as a mere verbal substitute for *Nucula* (Lam., 1799), as Dr. W. H. Dall and others have shown. Link's diagnosis applies to *Nucula* and not to *Leda* for he says that the shell is "smooth, closed all round." *Nuculana* (Link *non* Adams) is therefore "an exact synonym" of *Nucula* and cannot be sustained on the ground of priority. Consequently the family name *Nuculanidæ*, Adams, cannot be retained for *Ledidæ*. C. E. B.

Vestánafaltet: En Petrogenetisk Studie. (With an English Summary.) Af HELGE BACKSTROM. (127 pp., 8 pls. Kongl. Svenska Vetenskaps-Akadamiens Handlingar, Bandet 29, No. 4, 1897.)

The crystalline schists of the Vestana region, which lies in northeastern Scania, southern Sweden, have been studied and mapped in detail by Baron De Geer of the Geological Survey of Sweden. According to De Geer, they form an uninterrupted series of strata, striking northwest to northeast and dipping steeply to the west. From the youngest downward the sequence is as follows:

Klagstorp schists	Fine-grained grey gneiss. Dioryte-schist.
Dyneboda gneiss	Fine-grained, commonly red gneiss with layers of dioryte-schist.
Mica quartzyte	Mica-schist. Quartzyte. Mica-schist *with conglomerate*. Quartzyte with iron ore.
Dense fine-grained gneiss	Black, hornblende-bearing, dense fine-grained gneiss. Grey dense fine-grained gneiss. Grey gneiss, less fine-grained.

These gneisses and schists form a part of the Swedish Archæan (Lower Algonkian) and have been the subject of an able and painstaking investigation, from a petrogenetic point of view, by Dr. Bäckström.

Younger than the gneisses or crystalline schists there occur in the Vestana region numerous intrusive granite massives. Of these granites there is a prevalent fine-grained type ("Halen"-granite) and a less prevalent coarse-grained type ("Semshög" granite). These two types are closely related mineralogically and structurally. Both are characterized by scarceness of the ferromagnesian minerals and the predominance of microcline and quartz over oligoclase; hornblende is altogether absent; only biotite occurs; allanite and titanite are constant and often macroscopic constituents. Large microcline crystals are a characteristic feature of both granites, and give to them a porphyritic habit. This structure is called by Dr. Bäckström pseudoporphyritic, because the microcline does not belong to a first generation of crystallization, but, on the contrary, is younger than

the mica, oligoclase and orthoclase. There has been considerable recrystallization in these granites, which has affected the biotite, the oligoclase. the microcline and the quartz as well as the secondary minerals, and has thereby more or less altered the original structure. All the granites show the effect of pressure, but are distinctly separated by mineralogical composition from the gneisses. A crushed variety of the fine-grained granite is a granulite associated with the Dyneboda gneiss.

The mica-quartzyte belt is at its base a pure quartzyte. The hematite ore which this quartzyte contains is concentrated in narrow bands which are sometimes folded. The conglomerate, contained in the overlying mica-schist, is composed, for the most part (95 per cent), of boulders resembling the quartzyte beneath and for the remainder. of vein material. The mica-schist, or uppermost member of the mica-quartzyte band, is rich in muscovite and alumina minerals such as andalusite, cyanite, ottrelite and fibrolite. From this formation the author has elsewhere* described a "manganandalusite" which has the physical properties of common andalusite with the exception of a grass-green color and a strong pleochroism. The mica-quartzyte belt is connected with the conformable underlying dense fine-grained gneisses through gradations of mica-schist. Dr. Bäckström considers it possible, therefore, that the granite, being younger than the gneiss, is also younger than the mica-quartzyte. But none of the rocks of the latter formation now exhibit any distinct proofs of an original contact structure, the later tectonic movements having obliterated any older structure.

Amphibolites are associated subordinately with all the formations of the region, except the granites. Their principal occurrence is as a bed 100 meters thick between the quartzyte and the fine-grained gneisses. This bed, it is supposed, has been folded and appears as two beds enclosing the quartzyte. This amphibolite is composed of hornblende and plagioclase with subordinate biotite, orthoclase, quartz and epidote. Structurally three varieties are distinguished by the character of the hornblende: the feldspar always occurs in small anhedrons; the hornblende and mica may occur in anhedral grains or the hornblende occurs as idiomorphic prisms in a feldspathic ground-mass, or, finally, it may appear as large irregular grains. These amphibolites have the chemical composition of a diabase and the mineralogical and structural characters which have been known to be produced by the action of contact-metamorphism on a diabase. They lie within the contact zone of the granites, already described. For these reasons the amphibolite bed is thought to be either a diabase-flow or a layer of diabase tuff, while some of the minor occurrences of amphibolite are considered to be altered dyke rocks. In the Vestana region there are no unaltered diabases, gabbros or diorytes older than the intrusive granites or older than the orographic movement. There are, however, numerous dykes of unaltered

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*Geologiska Föreningens Förhandlingar, Stockholm, 1896, 18, p. 389.

diabases and norytes cutting the granites and showing themselves to be younger than the folding.

Conformably underlying the quartzyte and amphibolyte beds, occur the gneisses. The gneiss series begins with a dense fine-grained gneiss and passes by insensible gradations into a less fine-grained and more highly metamorphosed grey feldspathic gneiss, which covers the greater part of the eastern portion of the Vestana region. Interbedded with the gneisses are conformable layers of mica-schist, which show the structure and composition of sediments. The gneisses themselves have the chemical composition of quartz-diorytes and also show quartzes of the form common to the intelluric quartzes of effusive rocks. The gneisses are therefore regarded as resulting from the mechanical destruction of a quartz-porphyryte-tuff.

The southwestern and southern part of the area is occupied by a granite-gneiss. It is provisionally explained as an intrusive granite altered to a gneiss.

All the rocks of the Vestana region show more or less the effects of pressure, though only locally are the effects marked. Contact-metamorphism, however, has widely and strongly affected the sediments. In the quartzyte beds alone has this metamorphism been obliterated by the subsequent tectonic movements. This folding, affecting granite and sediments alike, pressed down between the lower and more highly metamorphosed gneisses a small part of the mica-quartzyte, once more widely extended, and the highest member of the gneissic series, and thereby saved them from removal by erosion.

The paper is accompanied by excellent photomicrographs and is a suggestive contribution to the understanding of the pre-Cambrian crystallines. The value of the petrographic study suffers some loss in the brevity of the English summary. F. B.

MONTHLY AUTHORS' CATALOGUE
OF AMERICAN GEOLOGICAL LITERATURE, ARRANGED ALPHABETICALLY.*

Adams, F. D.

The deformation of rocks under pressure. [Abstract.] (Eng. and Mining Jour., vol. 65, p. 522, Apr. 30, 1898.)

Adams, G. I.

Physiography of southeastern Kansas. (Kansas Univ. Quarterly, vol. 7, ser. A, pp. 87-102, Apr. 1898.)

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*This list includes titles of articles received up to the 20th of the preceding month, including general geology, physiography, paleontology, petrology and mineralogy.

Baker, Marcus.

A century of geography in the United States. (Science, new ser., vol. 7, pp. 541-551, Apr. 22, 1898.)

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CORRESPONDENCE

ON MR. FRANK LEVERETT'S CORRELATION OF [illegible] WITH BEACHES [illegible] LAKE ERIE. [illegible] Mr. [illegible] this journal Mr. Leverett opens a correspondence on my paper entitled "An account of the researches relating to the Great Lakes." He says that Dr. [illegible] has [illegible] in the February American Geologist [illegible] the supposed [illegible] of the [illegible] part of the region during the [illegible] that they [illegible] His further implies that I do not

regard the hypothesis of glacial dams as "a result of logical reasoning". The doctrine in favor of glacial dams is certainly no stronger and no more ably supported by distinguished opinions than was the question of glacial excavation of lake basins, which my investigations, in spite of the opposition at the time, have aided in dispelling. The change of opinion which has taken place in this great subject gives me confidence in not accepting the hypothesis of glacial dams based upon evidence which, although often plausible, recedes on being approached.

The first point in question is the hypothesis of the termination of deserted beaches against moraines. To reiterate, there are three notable examples where glacial dams have been theoretically located, namely at North Adams, New York, at Crittenden, New York, and at Cleveland, Ohio. At both Crittenden and Cleveland Mr. Leverett announced what he considered the termination of the beaches against moraines, which, if the facts were correct, would become very strong evidence. But in the case of North Adams I found the continuation of the Iroquois beach beyond that point, a fact since recognized by the author of the dam, Prof. Gilbert. Mr. Leverett's conclusions as to the termination of the Forest beach at Crittenden have since been set aside by Prof. Fairchild's discovery of its extension farther eastward without finding its termination. Again, at Cleveland Mr. Upham found that the beach extended beyond the morainic termination, and suggested that it probably reached ten miles farther. Thus when beaches have not been traced to their terminations against moraines, in the best known localities where such phenomena have been described, and failed of establishment, it seems illogical to cite such as a diagnosis of glacial dams;—the more so as contradictory evidence is suggested in the terraces farther east. Although I recognize the important contributions towards the final history of the Great lakes by those who use the glacial dam as a working hypothesis, yet the evidence so far adduced as to the location of the ice barriers themselves can only lead to the verdict of "not proven".

In my paper referred to I have mentioned terraces upon the southern side of the Adirondack mountains,—I may also add upon the southern and eastern sides of the White and Green mountains,—as occurring at hundreds of feet above the low lands, and having the same characteristics as the terraces upon the northern side of the mountains, which last have been regarded by some as originating in glacial dams. Although the observations extend over hundreds of miles and are of as much importance as the beaches about the western end of the lakes, they have been left unexplained by the advocates of glacial dams. Yet for several years I have thrown down the challenge for their elucidation. "Faith", says my critic, "in the harmony of the universe inspires confidence that the features of debatable origin, in which Dr. Spencer has taken refuge as a defense against glacial dams (page 117) and which have as yet received less attention than they merit, will some time be found consistent with the already well established facts and principles of geology, among which facts it seems safe to include glacial

dams". My faith in the uniformity of nature is not less strong than that of Mr. Leverett, and for this very reason when he includes among "established facts" glacial dams, based upon evidence which is found to be elusive, and when he ignores phenomena which he says have received less attention than they merit, although they are of fundamental importance, one's reason compels him to halt before such a doctrine, and to discredit the acceptance of an hypothesis against which such powerful facts appear.

Another class of phenomena embraces the channels across divides, frequently characterized by gravel floors, and where such are found they have often been considered as evidences per se of the outlets of glacial lakes. Against this interpretation I have already pointed out that we find terraces of similar hight upon both the southern and northern sides of the plateaus,—or outside and inside the glacial dams. Furthermore phenomena exactly similar to the so-called outlets of glacial lakes are seen at low altitudes within a few degrees of the equator, as for example in the Tehuantepec isthmus in Mexico, an illustration of which may be seen in the accompanying figure. Upon the Atlantic side there is an extensive gravel terrace corresponding to the gravel floor of the channel across the divide, which is an exact reproduction of the so-called glacial lake outlets of the north. This geological canal is less than a mile long and a hundred and fifty feet deep. Upon the Pacific side the descent is so rapid that the corresponding terrace-like features have been washed away. The characteristics of this channel over the divide are almost like those at Crawford

FIG. 1. Northern end of channel or geological canal over the Tehuantepec divide.

notch in the White mountains where the gravel terraces have been removed from the immediate cañon on the one side, but characterize the other end of the notch. No one can associate this Tehuantepec canal with glacial dams. So long as such features in the lake and mountain regions are produced by other causes than the outflow of glacial dams it seems quite logical to question the verity of such evidence in their favor, especially when the elevated terraces on the southern side of the highlands throughout a region of hundreds of miles in length indicate open water where glacial dams should occur. Thus the great volume of evidence that can be obtained through observations of these classes of phenomena is very much more than a "refuge" in support of the objections against the claimed establishment of the doctrine of glacial dams, the location of which has proved, so far, indefinite.

The advocates of glacial dams have taken it upon themselves to prove their late existence;—and when they have accurately located them, brought the high terraces upon the southern and eastern sides of the plateaus into harmony with their hypothesis, and established that the present channels over divides are evidence per se of glacial dams;—then we shall be ready to accept their hypothesis as the result of logical induction. But until then the pronunciamento that glacial dams "seem established facts and principles of geology" must be doubted by independent investigators.

Washington, D. C., March 24, 1898. J. W. SPENCER.

PERSONAL AND SCIENTIFIC NEWS.

THE UNIVERSITY OF NEW MEXICO, at Albuquerque, is to have a practical summer school in geology and mining under the charge of the president, C. L. Herrick. Two months will be spent in topographical and geological work in the Magdalene mountains. Arrangements have been made whereby a limited number of students not members of the University can attend this summer school.

THE NATIONAL ACADEMY OF SCIENCES held its annual stated session in Washington on April 19th to 22nd. The most interesting paper presented, from a geological standpoint, was by Prof. Alexander Agassiz on "The coral reefs of Fiji." Other papers of interest to geologists were: "Biographical memoir of E. D. Cope" by Theodore Gill; "New classification of the Nautiloidea" by Alpheus Hyatt. No new members of the Academy were elected, but a number of foreign associates were added, among whom are the geologists Prof. Edward Suess, of Vienna, and Prof. Karl Alfred von Zittel, of Munich.

THE ACADEMY OF SCIENCES OF ST. LOUIS. Prof. Frederick Starr, in Appletons' Popular Science Monthly for March, gives the history and a sketch of the work of this important, pioneer, western association. Several portraits of prominent members of the Academy are given and among these are the geologists B. F. Shumard and G. C. Swallow.

GEOLOGICAL SOCIETY OF WASHINGTON. At the meeting of March 9th the following papers were presented:

The Mesozoic section Sierra Blanca, Texas. T. W. Stanton.
The Belly River horizon on the upper Missouri river. F. H. Knowlton.
Trachandesite flows of the Sierra Nevada. F. L. Ransome.

At the meeting of March 23rd the following papers were presented:

Crystalline schists and rock flowage. C. R. Van Hise.
Igneous phenomena in the Tintic mountains, Utah. G. C. Smith.
A "blow-out" near Mancos, Colorado. A. C. Spencer.

At the meeting of April 13th the following papers were presented:

Geology of the McAlester quadrangle. J. A. Taff.
The probable age of the McAlester coal group. David White.
The Franklin and Nomini folios. N. H. Darton.
On the succession of the igneous rocks of the Sierra Nevada. H. W. Turner.

At the meeting of April 27th the following papers were presented:

Methods of obtaining geothermal data. N. H. Darton.
Volcanic rocks of the Piedmont region. Arthur Keith.
Mining geology of the Tintic mountains, Utah. G. W. Tower, Jr.

At the meeting of May 11th the following papers were presented:

Mountains of northern Montana. W. H. Weed.
The La Plata mountains, Colo. Whitman Cross.

M. STANISLAS MEUNIER has begun a course of lectures in experimental geology at the Paris Museum of Natural History. He discusses the various attempts that have been made to reproduce geological phenomena artificially.

MR. JAMES P. KIMBALL, of New York City, will spend the summer in surveying a belt of country in Montana between Red Lodge and the Yellowstone. His address will be U. S. Assay Office, Helena, Montana.

MR. HORACE V. WINCHELL, of Minneapolis, has accepted the position of geologist for the Anaconda Copper Mining company at Butte, Montana.

NEW YORK ACADEMY OF SCIENCES. Section of Geology and Mineralogy. April 18th, 1898.

The first paper of the evening was by Dr. A. A. Julien, on "The Elements of Strength and Weakness in Building Stones." Dr. Julien called attention to the fact that in the

testing of building stones little consideration is given to the causes influencing their various properties. In judging the resistance, which a stone shows towards weathering, care should be taken to recognize the character of the forces to which it has been subjected. The strength of a stone bears no relation to its mineral components, but is dependent on the shape and arrangement of the mineral grains and character of the cementing material. In considering the strength of a stone four facts have to be kept in mind, viz.: interlockment of the particles; coherence, dependent on character of the cement and adhesion of the grains; rigidity; and tension.

The "quarry sap," Dr. Julien believes, plays a more important role than has hitherto been recognized, as it probably carries much of the cement in solution and deposits it only when the stone is exposed to the air. This accounts for the hardening of the stones after being quarried. A distinction should also be made between porosity due to cavities between the grains and that due to interstices in the individual minerals. The former is a source of weakness, the latter not, although either may cause the rock to exhibit a high absorptive capacity. All of these points which have an important bearing on the strength of building stones are best studied with the microscope. The paper was illustrated by means of sections thrown on the screen with a polarizing lantern. Discussion was by Prof. Kemp and Mrs. Dudley.

The second paper of the evening was by J. D. Irving, on "Contact-metamorphism of the Palisades Diabase." Mr. Irving referred to the work done by Profs. Osann and Andrae some years ago, and stated that his results agreed with theirs, but recent railroad excavations at Shadyside had enabled him to obtain additional facts. The diabase flow becomes denser, finer grained and porphyritic towards the contact, with a decrease in hypersthene. It is also conformable with the Newark shales. In addition to the zones found by Osann, Mr. Irving found: (1) a normal hornfels zone rich in Spinel; (2) a hornfels zone with brown basaltic hornblende layers; (3) hornfels with an undeterminable isotropic mineral resembling leucite; (4) hornfels with andalusite, becoming arkose farther from the contact. This diabase is to be considered as an intruded mass and not a surface flow. The paper was discussed by Profs. Kemp and Dodge, Dr. Hovey and Mr. White.

HEINRICH RIES, *Secretary*.

INDEX TO VOL. XXI.

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James T. [illegible]	MAY 10 1967	
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